# Beyond the Forest and the Trees:
# A Cross-Sectional Investigation into Local and Global Information Processing in Visual Perception and Language in Typical Development and Autism Spectrum Disorder

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Doctor of Philosophy

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This investigation aimed to deepen our understanding of local and global processing (LGP) in visual perception and language in typical development (TD) and autism spectrum disorders (ASD). In TD, a global bias is commonly found, while results for ASD vary. Still unclear is whether LGP in ASD follow developmental trajectories that are delayed or qualitatively different, but also whether it is indeed atypical. Uncertain is also how stimulus- and task-dependent factors influence processing styles. These issues were explored. A further aim was to illuminate the applicability of explanatory theories for poorer global processing in ASD: weak central coherence (WCC), language impairment (LI), and executive dysfunction (ED) theory.

After an introductory Chapter 1, Chapters 2 to 4 give a review of the literature regarding LGP in vision and language, followed by an overview of the aims of this investigation (Chapter 5) and the methodology (Chapter 6). The first experimental study (Chapter 7) addressed perceptual and cognitive aspects of LGP in TD adults and demonstrated a flexible global bias which was mainly independent of stimulus characteristics. The next two studies included cross-sectional TD and ASD samples that were tested on a wider battery of visual (Chapter 8) and language tasks (Chapter 9) in order to investigate developmental aspects of LGP, compare processing in the typical and clinical sample, and examine the relationship of different LGP tasks within and across domains as well as the links between LGP, language abilities, and autistic traits (Chapter 10).

The analyses revealed that the ASD groups performed in a manner comparable to TD participants, although there were indications for a developmental delay in ASD. LGP indicators did not correlate within or between modalities. Neither the WCC nor LI theory were fully supported by the findings. Instead, ED are suggested to be the underlying factor that influenced performance.

Key Words: autism, development, hierarchical figures, cognitive style, global precedence, flexibility, weak central coherence, executive function

*For my little Emilia*

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# List of Abbreviations and Acronyms

| | |
|---|---|
| ACC | Accuracy |
| ADHD | Attention-deficit hyperactivity disorder |
| ADI | Autism Diagnostic Interview |
| ADOS | Autism Diagnostic Observation Schedule |
| AMBSENT | Ambiguous Sentences |
| AMBWORD | Ambiguous Words |
| AQ | Autism Spectrum Quotient |
| AS | Asperger Disorder/Syndrome |
| ASD | Autism Spectrum Disorder |
| BD | Block Design |
| BI | Bias Indicator |
| CC | Central Coherence |
| CCA | Communication Checklist for Adults |
| CCC | Children's Communication Checklist |
| CE | Contingency Effect |
| CFR | Contextual Facilitation Ratio |
| CLB | Content-Level-Binding (Theory) |
| CONTI | Experiment/Task: Contingencies |
| CONTMASK | Experiment/Task: Contingencies with Masking |
| CS | Completion Score |
| CSR | Contextual Suppression Ratio |
| CSS | Childhood disintegrative disorder |
| DAS | Dominant Advantage Score |
| DISCO | Diagnostic Interview for Social and Communication Disorders |
| DSM | Diagnostic and Statistical Manual of Mental Disorders |
| ED | Executive Dysfunction (Theory) |
| EF | Executive Function |
| EFT | Embedded Figures Test |
| EPF | Enhanced Perceptual Functioning (Theory) |
| FD | Field Dependence |
| FI | Field Independence |
| FSIQ | Full-Scale IQ |
| G100 | 100% of targets on the global level |
| G20L80 | 20% of targets on the global level, 80% local |
| G50L50 | 50% of targets on the global and local level |
| GPE | Global Precedence Effect |
| HFA | High Functioning Autism |
| IQ | Intelligence Quotient |
| L100 | 100% of targets on the local level |
| L80L20 | 80% of targets on the global level, 20% local |
| LANTA | Study: LGP in Language in TD and ASD |
| LC | Local Completions |
| LGLP | Local and Global Language Processing |

| | |
|---|---|
| LGP | Local and Global Processing |
| LI | Language Impairment |
| LONG | VISTA block: Stimulus duration 3000ms |
| LPE | Local Precedence |
| MASK | VISTA block: 50% targets on either level for 150ms followed by 50ms mask |
| NHS | National Health Service |
| NVP | Nonverbal Performance |
| PDD-NOS | Pervasive developmental disorder, not otherwise specified |
| PE | Priming Effect |
| PECOG | Study: Perceptual and Cognitive Factors of LGP in TD |
| PESC | Priming Effect or Switch Cost |
| PICNAME | Picture Naming Task (Pilot Study) |
| RT | Reaction Time |
| SCQ | Social Communication Questionnaire |
| SENTCOMP | Sentence Completion |
| SENTORD | Sentence Ordering |
| SHORT | VISTA block: see G50L50, stimulus duration 150ms |
| SLI | Specific Language Impairment |
| STIMMIX | Experiment/Task: Stimulus Mix |
| TD | Typical Development / Typically Developing |
| TempFR | Temporal Facilitation Ratio |
| TFR | Total Facilitation Ratio |
| TIS | Total Interference Score |
| ToM | Theory of Mind |
| VA | Visual Angle |
| VISTA | Study: LGP in Vision in TD and ASD |
| VOCAB-CHECK | Vocabulary check of ambiguous words |
| VP | Verbal Performance |
| WASI | Wechsler Abbreviated Scale of Intelligence |
| WCC | Weak Central Coherence (Theory) |
| WORDASSO | Word Association Task (Pilot Study) |

# List of Contents

# List of Figures

# List of Tables

# 1 Introduction to Autism Spectrum Disorders and Local and Global Processing

## 1.1 Overview: Autism Spectrum Disorders

Autism Spectrum Disorder (ASD) affects approx. 1.1% of the UK population (The NHS Information Centre et al., 2012). It was first described by Kanner in 1943 who presented 11 case reports (8 boys and 3 girls) of 'infantile autism'. These children showed *"extreme autistic aloneness"*, they were *"self-sufficient"* and *"happiest when alone"* (Kanner, 1943, p. 242). In addition, language was acquired either at the usual age, with a delay, or was missing completely. When language was present, sentence production was impaired, whereas object naming was good. The children showed *"monously repetitious"* behaviour, an *"anxiously obsessive desire for the maintenance of sameness"* and became *"greatly disturbed by the sight of anything broken or incomplete"* (p. 245). Kanner also mentioned *"the inability to experience wholes without full attention to the constituent parts"* and that "*a situation, a performance, a sentence is not regarded as complete if it is not made up of exactly the same elements that were present at the time the child was first confronted with it. If the slightest ingredient is altered or removed, the total situation is no longer the same and therefore is not accepted as such*" (p. 246).

Kanner's early descriptions exemplified the so-called dyad of impairments that generally characterise individuals with ASD. The current Diagnostic and Statistical Manual of Mental Disorders (DSM-5, American Psychiatric Association, 2013) defines ASD as a *deficit in social communication and interaction*, as well as *restrictive and repetitive behaviour and interests*. Previously seen as a triad (Figure 1.1), not dyad, those are largely independent, although interacting dimensions (Happe & Booth, 2008), leading to a rather heterogeneous presentation of people with ASD. For example, Hobson (2014) points out that ASD is a syndrome and thus, various constellations of relevant clinical features can be encountered.

ASD belongs to the group of neurodevelopmental disorders; and, in the majority of cases, it co-occurs with other neurodevelopmental disorders including e.g. dyslexia or attention-deficit hyperactivity disorder ADHD (ADHD, Russell & Pavelka, 2013).

Although currently, ASD is classed as one overarching syndrome, previously (DSM-4, American Psychiatric Association, 2000), it was divided into subgroups with separate diagnostic labels which varied regarding intellectual and language abilities as well as severity and type of symptoms. In research studies, participants are often described as belonging to one of those subgroups:

- Autistic disorder/autism (e.g. Chen et al., 2012)
- Autistic disorder with high functioning autism (HFA; Bavin et al., 2014: IQ > 70; Hayward et al., 2012: IQ > 80; ) with significant language delay in childhood. Note, that HFA was not an official diagnostic term (e.g. Quintin, Bhatara, Poissant, Fombonne, & Levitin, 2013; Scherf, Luna, Kimchi, Minshew, & Behrmann, 2008)
- Asperger disorder/syndrome (AS, IQ> 80, no significant language delay in childhood, e.g. Chen et al., 2012; Katagiri, Kasai, Kamio, & Murohashi, 2013)
- Pervasive developmental disorder, not otherwise specified (PDD-NOS), also referred to as "atypical autism" (e.g. Chen et al., 2012; Tovar, Fein, & Naigles, 2015)
- Rett syndrome (no longer seen as a subtype of ASD in DSM-5)
- Childhood disintegrative disorder (CDD)

The current research included children with formal diagnoses of 'Asperger syndrome', 'Autism', 'High Functioning Autism', 'atypical Autism', and 'ASD'. Note, however, that for the purpose of the current work, the umbrella term (DSM-5) 'ASD' will be used to describe all participants.

When discussing ASD and accompanied (negative) symptoms, it can be overlooked that some individuals with this diagnosis can also exhibit positive attributes like potential savant skills (e.g. exceptional memory, artistic, musical or language talent) which are often based on an extraordinary attention to detail. Yet, although the 1988 movie Rain Man has spread the view that autistic people automatically have special talents,  this is the case only for approx. 10% of people with the diagnosis; the majority have normal or below average skills (Treffert, 2009).

Figure 1.1 illustrates the triad of impairments in ASD (as suggested in DSM-IV-TR, American Psychiatric Association, 2000) while giving space for potential talents. Part of those negative and positive symptoms can be explained by the Weak Central Coherence Theory (WCC, Frith, 1989). According to this theory, autistic people exhibit an increased focus on details, and thereby disregard the whole, overall gestalt. This can go along with excessive engagement with certain objects or topics, but also a disability in combing information from separate sources—an important skill in daily life that helps us to understand other people and situations and to predict behaviour and events through generalisation and knowledge transfer. If these skills are missing, individuals will inevitably struggle (e.g. Frith, 1989).

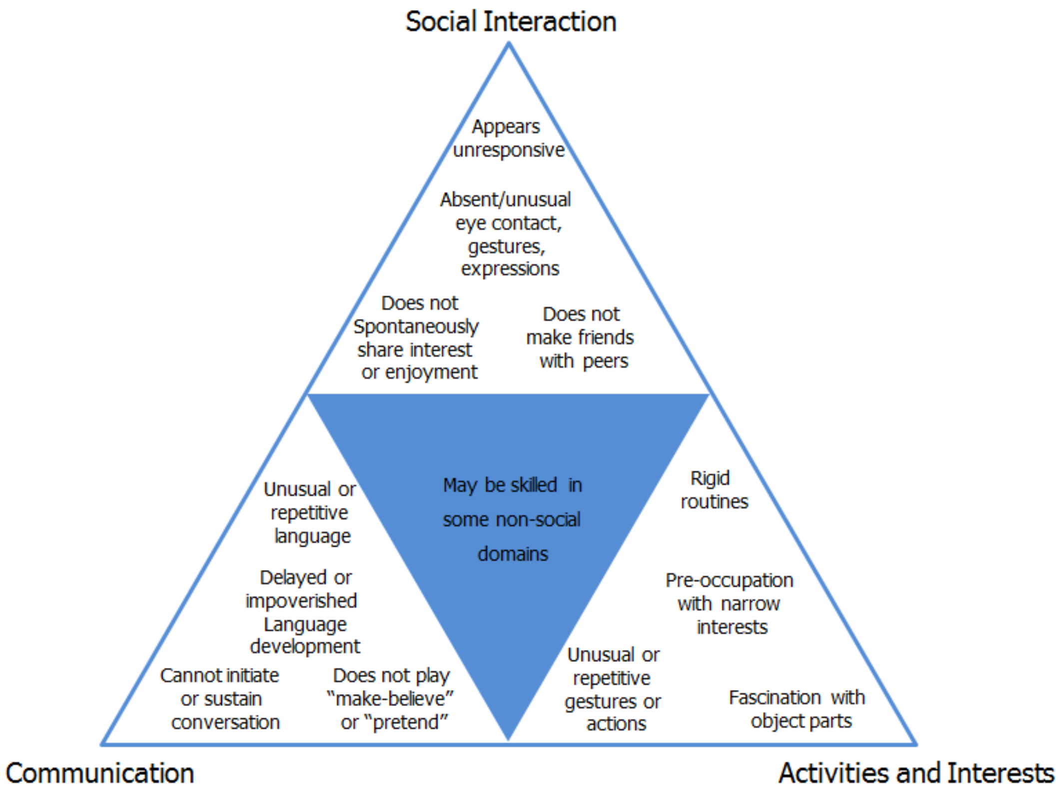


*Figure 1.1.* The triad of impairments in ASD: Social Interaction, Behaviour Inflexibility, Communication (based on DSM-IV-TR, figure adapted from the National Autistic Society, accessed 16.12.2013 on http://labspace.open.ac.uk/mod/resource/view.php?id=482959).

## 1.2 Prevalence

Diagnoses of ASD are more common in males, a bias that has been widely reported among ASD researchers: Often found male-to-female ratios are 5.5:1 (Fombonne, Quirke, & Hagen, 2011) and 4:1 (Baio, Wiggins, Christensen, & al., 2018; Fombonne, 2009). However, newer research suggests that the real gender ratio is much more balanced: a recent systematic review and meta-analysis concluded that the ratio was close to 3:1 (Loomes, Hull, & Mandy, 2017). ASD is not detected as easily in females, as ASD symptoms are more 'acceptable' in girls leading to a diagnostic gender bias (Dean, Harwood, & Kasari, 2017; Loomes et al., 2017). The gender discrepancy has further been attributed to differences in the autism phenotype between males and females (Holtmann, Bolte, & Poustka, 2007; Lai, Baron-Cohen, & Buxbaum, 2015; Lai et al., 2012; Supekar & Menon, 2015) and the possibility that females are better able to compensate for their difficulties (Dworzynski, Ronald, Bolton, & Happe, 2012).

The median prevalence for ASD worldwide is 0.6% (Elsabbagh et al., 2012), whereas in the UK it is 1.1% (The NHS Information Centre et al., 2012). However, in a South Korean study (Kim et al., 2011), the prevalence was reported at 2.64% (1.89% in the general population and 0.75% in a high-probability group). Differences in the prevalence may be due to varying diagnostic criteria or different awareness of the disorder (Elsabbagh et al., 2012). As the diagnostic criteria were recently modified in the DSM-5 compared to the earlier DSM-IV-TR, it is possible that the findings of future prevalence studies based on the DSM-5 criteria will also change. For example, Maenner et al. (2014) reported in their study including over 640 000 children in the US, that 6577 (1%) met the diagnostic criteria for ASD based on DSM-IV. From those, only 81.2% (5339 or 0.8% of the total sample) also met the DSM-5 criteria, whereas 304 of all children (0.05%) met the DSM-5 but not DSM-IV criteria. Concluding, the prevalence in this overall sample was 1.13% using DSM-IV-TR criteria and 1.0% using DSM-5.

## 1.3 Assessment of ASD

In clinical contexts, ASD is diagnosed using the criteria of the DSM-5 (American Psychiatric Association, 2013) or ICD-10 (Organisation, 1992). Often utilised measures for clinical and research purposes are:

- the Autism Diagnostic Observation Schedule (ADOS, Lord, DiLavore, K., Guthrie, & Luyster, 2012),
- Autism Diagnostic Interview (ADI, Rutter, LeCouteur, & Lord, 2008), or
- Diagnostic Interview for Social and Communication Disorders (DISCO, Wing, Leekam, Libby, Gould, & Larcombe, 2002).

Research studies also further apply the

- Autism Spectrum Quotient (AQ, Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008; Baron-Cohen, Hoekstra, Knickmeyer, & Wheelwright, 2006; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001),
- Social Communication Questionnaire (SCQ, Rutter, Bailey, & Lord, 2003), or
- Children’s Communication Checklist (CCC, Bishop, 2003) / Communication Checklist for Adults (CCA, Whitehouse & Bishop, 2009).

The latter three have also been included in the current projects and are presented in more detail in the General methods section (Section 6.7) and Appendix E.

## 1.4 Introduction to theories of autism

A large body of theories has been developed trying to explain ASD on the genetic, neural and cognitive levels. The most popular among the cognitive theories are:

- The Weak Central Coherence Theory (Frith, 1989; U. Frith, 2003; Happe, 1999; Happe, Briskman, & Frith, 2001; Happe & Frith, 2006)
- The Enhanced Perceptual Functioning Theory (Plaisted, O'Riordan, & Baron-Cohen, 1998)

- The Executive Dysfunction Theory (Ozonoff, Pennington, & Rogers, 1991),
- The Theory of Mind Deficit Account (Baron-Cohen, Leslie, & Frith, 1985)

One reason for the number of different theories is that none of them has been found to account for all symptoms and variation in ASD. Slightly newer theories claim to be unifying theories presenting underlying causes for all encountered symptoms in autism (e.g. Intensive World Theory, Markram & Markram, 2010; Learning-Style Theory of Autism, Qian & Lipkin, 2011). However, the more research is conducted on autism, the more questions seem to arise that current theories are not able to answer fully. Fittingly, Happe, Ronald, and Plomin (2006) recommend that it is *"time to give up on a single explanation for autism"* (p. 1218) and *"to give up on the search for a monolithic cause or explanation for the three core aspects of autism, at the genetic, neural and cognitive levels"* (p. 1219).

More detailed information about autism theories can be found in Section 3.2.

## 1.5 What is local and global processing?

When perceiving the world around us, we are constantly engaged in local and global processing (LGP). The term *local* refers to details and separate elements, whereas the term *global* applies to the gestalt or the overall picture. LGP is apparent in the visual domain, but also in all other ones, including the auditory, olfactory, gustatory, tactile, and language domains.

For example, when entering a room, one could get either get an overall picture of it (e.g. *"I see an office"*) or perceive only the details *("I see a desk, 14 books and 3 used coffee mugs of which one is half empty"*) without necessarily combining them *("…this must be an office").* In other domains, i.e. listening to a concert, one can concentrate on the overall sound experience or on the progression of separate voices or instruments. When smelling, the whole odour of a perfume can be perceived or all different fragrances can be distinguished. When identifying objects, for example, a key, through touch, one could focus on the overall form *("It is a key")* or try to feel the exact shape of the teeth of the key. In language, local elements could be understood as separate words and simple grammar (e.g. declension, conjugation), whereas the meaning of a sentence, especially figurative language represents the global aspect.

Closely related to LGP are the terms global precedence and central coherence. Global precedence (Navon, 1977) describes the predisposition to perceive global aspects of a scene or stimulus first and to process local information only later (synonyms: global bias, global advantage). Central Coherence is understood as the tendency to process information in its given context and to draw diverse information together in order to construct higher-level meaning (Frith & Happe, 1994). One distinguishes between strong central coherence (related to global bias, presumably predominant in TD) and weak central coherence (related to local bias). Weak central coherence is presumably predominant in ASD—they can't see the forest (global) for the trees (local).

## 1.6 Overview of the aims of the dissertation

This dissertation sought to examine LGP in visual perception and language in typical development (TD) and in individuals with ASD. The aims were to investigate processing in TD children, adolescents and adults in order to determine normative developmental trajectories for LGP in vision and language tasks, and, drawing upon those findings, to compare them to the data from a cross-sectional sample of individuals with ASD with the aim of establishing whether or not processing in ASD is atypical and if so, whether it is developmental delayed or qualitatively different.

More specifically, processing biases in visual perception were examined, what factors influenced processing biases, and how flexibly they could be overcome. In language, aspects of LGP were assessed including the ability to use sentence context in order to facilitate or suppress relevant/irrelevant meanings of ambiguous words, the ability to understand and use local/global information in written text, and the presence of general global/local processing styles in language.

The following literature review will provide deeper insight into the relevant aspects of this investigation. The literature review gives an extensive overview of the current state of research regarding LGP in visual perception and language in TD and ASD. It is divided into three parts: The first two cover LGP in vision in TD (Chapter 2) and in ASD (Chapter 3), and Chapter 4 presents local and global language processing (focussing on ASD).

# 2 Local and Global Processing in Typical Development

## 2.1 Chapter overview

This chapter provides theoretical background information about LGP in typical development (TD). First, global precedence and related concepts will be introduced, followed by a discussion of whether LGP are one dichotomous construct located on different ends of the same continuum or whether they rather lie on separate continuums. Second, research evaluating interindividual and stimulus/task-dependent aspects that influence LGP will be reviewed. Finally, the idea of priming, its variations and use for LGP research will be discussed.

## 2.2 Three related concepts: global precedence, field dependence and central coherence

Translating what we see in the world around us and creating understandable and interpretable images of it in our heads is a complex process. Visual processing is usually described as developing from a more general percept to more detailed processing. The idea first emerged in the area of Gestalt psychology: perception of stimuli is initially organised in a top-down fashion and by grouping principles; only later, separate parts are analysed (see for a review Happe & Booth, 2008; Wertheimer, 1938). Marr (1976) explained in his theory of visual processing how it relies on an analysis going from the rough global sketch down to the details. When encountering a scene, first, a primal sketch is formed based on edges, ends, lines, groups, and boundaries. Then a 2 ½-D sketch is produced that includes information about the orientation and depth of the surfaces. It is only after this step is completed, that a full 3-D model representation emerges. It is hierarchically organised from larger elements to smaller details with continuously more precise information.

Navon (1977) similarly suggested that a *global* percept is formed initially which is subsequently decomposed into its *local* elements. The global precedence effect (GPE, a term coined by Navon) describes the phenomenon that our perceptual system is more inclined to perceive the overall form than the local details. Navon (1977, 1981) could demonstrate in a range of experiments with hierarchical figures (figures with a global and local level where the global form, e.g. the letter H, is made out of local elements, e.g. the letter S, see Figure 2.1) that participants experienced greater interference from global features in incongruent stimuli (i.e. with different information on the global and local level) than from local features. Participants were also better able to point out differences between pairs of figures based on global features than local ones.

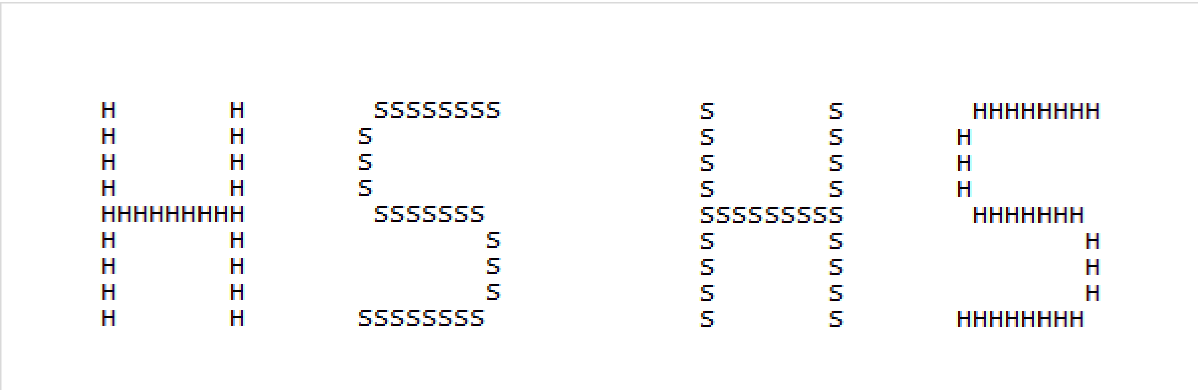

*Figure 2.1.* Examples for hierarchical Figures adapted from Navon (1977).
Left letters show congruent local and global levels (H & S), right letters show incongruent local (S & H) and global levels (H &S).

Field dependence (FD) and independence are terms related to the GPE which are used to describe *cognitive styles* (Witkin, Moore, Goodenough, & Cox, 1977). A field independent (FI) cognitive style describes the perception of elements which is largely independent of the surrounding ground (local), whereas in FD the ground is more salient and the percept is processed as a whole (global). Poirel, Pineau, Jobard, and Mellet (2008) showed that the degree of FD in an individual is linearly related to their global bias in a hierarchical task (but see Chamberlain, Van der Hallen, Huygelier, Van de Cruys, & Wagemans, 2017, who showed low correlations between an FD measure and Navon task). FD/FI can be tested, for example, by the Embedded Figures Test (EFT) by Witkin, Oltman, Raskin, and Karp (1971) where a simple target element is embedded into a more complex figure. Individuals with FI are faster in discovering the embedded figures than those who exhibit more FD. This and other tests are commonly used to assess not only FD/FI but also LGP (e.g. Ropar & Mitchell, 2001; Shah & Frith, 1983, 1993) and a third related concept: central coherence (Milne & Szczerbinski, 2009).

## 2.3 Central coherence: one or two continuums?

Central coherence (CC) is understood as the drive to process information in its given context which is like a "*strong force pulling all the information in the picture together*" (U. Frith, 2003, p. 154). Happe (1999) suggested a continuum from strong central coherence to weak central coherence (see Figure 2.2). TD individuals tend to perceive the world more globally and use context for their perception (so they are located towards the end of strong CC), whereas individuals with ASD rather concentrate on details (and tend towards weak CC).

One might wonder, how exactly TD and ASD could be distributed on this continuum of central coherence. Three possible accounts have been put forward: First, they could have two separate bell-shaped distributions on the same continuum, with TD and ASD individuals varying around an average or their respective groups (Figure 2.2a). Second, a unimodal distribution might be possible: ASD and TD belong to the same normal distribution but people with ASD are located towards the extreme end of that distribution (Figure 2.2b). Third, TD and ASD might not be located on the same continuum but show qualitative differences. However, so far, no answer has been found to the question whether ASD and TD are on the same ('normal') continuum of coherence (e.g. with a bimodal trait distribution) or show qualitative differences (Happe, 1999; Skuse, Mandy, & Scourfield, 2005). Potentially, individuals with ASD show an atypical, deviant development regarding central coherence or it might be a developmental delay where they reach TD adult-like strong coherence only at a later stage in life.

However, while strong and weak central coherence (or FD/FI, local/global processing) were originally seen as a dichotomous construct with two ends on one continuum (as depicted in Figure 2.2), there is growing support for the notion that there are actually two separate continuums for local and global processing. Processing styles could be depicted in a four-field matrix with strong and weak ends for both local and global processing (Figure 2.3). Thus, individuals can show efficient processing in either, both, or none of the processing modes and they vary in the extent to which they can flexibly shift between processing styles (e.g. Evans, Richardson, & Waring, 2013; Happe & Booth, 2008; Happe & Frith, 2006; Huizinga, Burack, & Van der Molen, 2010; Niaz, 1987; Pletzer, Scheuringer, & Scherndl, 2017).

*Figure 2.2.* Possible distributions of central coherence in TD and ASD.
a) Central coherence and autistic traits as a continuum with two bell-shaped curves for TD and ASD as proposed by Happe (1999). b) Alternative unimodal presentation with ASD at the extreme end of the continuum.



*Figure 2.3.* Four combinations of possible LGP abilities of individuals as suggested by Happe and Frith (2006).
A: weak global and strong local abilities; B: strong global and strong local abilities; C: weak global and weak global abilities; D: strong global and weak local abilities.

According to Happe and Booth's review (2008), performance in both, tasks requiring global processing (e.g. extracting gist, showing global precedence effects) and those requiring local processing (e.g. EFT, Block Design (BD, Wechsler, 1998) improve with age. This supports the idea that these processing styles are not on one continuum but develop alongside each other. Similarly, Niaz (1987) suggests that FD represents an earlier mode of functioning, whereas FI is an advanced mode, and that there is an interindividually varying degree of how flexibly one can change between those modes. Likewise, Huizinga et al. (2010) claimed that global processing develops to adult-like levels before local processing does, but that it is the flexibility of changing between levels that shows greater developmental maturity in individuals. Kholodnaya (2002, as cited in Kozhevnikov, 2007) takes this even further suggesting that cognitive styles are present only in flexible individuals; and that inflexible individuals (with a fixed style of either FI or FD) have a cognitive deficit.

One then has to question, where in the 4-field matrix would lie the majority of TD individuals and those with ASD. Potentially, when allocated to processing preferences, the majority of individuals with ASD would be found in square A (weak global, strong local), whereas TD would be more represented in square B (strong global and local). The question arises whether maybe the majority of differences found in visual processing between TD and ASD stem from less efficient shifting in ASD, i.e. participants with ASD could be impaired in overcoming their (local) processing preference. Booth (2006) found in her dissertation that although there was a positive correlation between local and global processing in TD, this was not the case in ASD where there was a trade-off between the processing levels.

## 2.4 Developmental aspects of processing styles

Huizinga et al. (2010) reported that the global advantage effect was strongest in children and decreased with age (but was still apparent in adults). Nevertheless, the usual consensus is that children rather have a local advantage and that global processing abilities develop with age (e.g. Kimchi, 2014; Kimchi, Hadad, Behrmann, & Palmer, 2005; Nayar, Franchak, Adolph, & Kiorpes, 2015; Oishi et al., 2014; Poirel, Mellet, Houde, & Pineau, 2008; Scherf, Behrmann, Kimchi, & Luna, 2009; Scherf et al., 2008); however, there is less consensus when this development takes place.

For example, some researchers reported that global processing was already present in four-month-old infants before local processing was established (Freeseman, Colombo, & Coldren, 1993). Smith, Yu, and Pereira (2011) demonstrated that toddlers aged 17-19 months showed a local perception style in visual scenes by concentrating on single objects and its fragmented features, which poses an advantage to learning and visual selection by initiating object segregation, integration and attention stabilisation. Between 18 and 24 months of age, this changed to a (less local) perception style of geometric features and 3D shapes (Smith, 2009). Nayar et al. (2015) applied an illusory contour perception task on 3 to 10-year olds, in which shapes with holistic contours based on illusory edges (which represents global holistic processing) had to be compared with fully contoured sample shapes. They concluded from their findings that the (gradual) shift from local to global processing happens between the ages 4 and 7 with adult processing levels attained by the age of 7 or 8. On the other hand, others conclude that global preference replaces local preference at 9 years of age (Poirel, Mellet, et al., 2008) and that 7-year old children had a weaker global bias than adults (Krakowski, Borst, Vidal, Houde, & Poirel, 2018).

Meanwhile, in contrast to the above studies, other research groups reported global processing not reaching adult level until adolescence (Kimchi et al., 2005; Scherf et al., 2009; Scherf et al., 2008). Scherf et al. and Kimchi et al. further showed that the characteristics of the stimuli, i.e. whether there were many or few small or large local elements forming the global percept, played a role: Younger participants were more likely to perceive the global forms when stimuli consisted of many small elements (e.g. 4x4 squares) compared to few large elements (2x2 squares). Individuating few large elements and grouping of many small elements were proficient already in young children. Individuating many small and grouping few large elements was developed with age from childhood to adolescence where it reached adult level. Similarly, Neiworth, Gleichman, Olinick, and Lamp (2006) reported that children showed a global preference in denser stimuli but no bias in sparse displays, whereas adults had a global bias in either condition.

The question arises whether the global processing advantage in adulthood remain constant until old age. Research suggests that there is a decline of global precedence in older subjects (Staudinger, Fink, Mackay, & Lux, 2011) or even local precedence (Slavin, Mattingley, Bradshaw, & Storey, 2002).

Despite this, Bruyer and Scailquin (2000) report no group difference in global precedence between younger (18-21 years) and older adults (65-74 years); there was, however, a subgroup of elderly participants who did not show global interference effects.

According to Kimchi (2014) inconsistent findings regarding participants' age and local or global processing preferences or abilities might stem from the use of different experimental tasks: Global processing (grouping) might be sufficient in children to complete simpler tasks, e.g. in visual search tasks (where a globally or locally defined target has to be detected whilst being surrounded by a number of distractors) or in classification tasks (where patterns have to be classified by local or global characteristics to one or the other group (Kimchi et al., 2005). However, more complicated tasks, e.g. with short presentation times like in Scherf et al. (2009), require higher abilities that do not emerge until late adolescence.

However, due to the discussed evidence above about processing modes developing alongside each other (Section 2.3), we would argue that a distinction should be made between processing *abilities* and processing *preferences*. We therefore suggest that the developmental trajectory described above and depicted in Figure 2.4 represents much more the development of processing preferences, in contrast to processing abilities. Taken together the background research suggests a trend towards a global processing in the early months of life, followed by local precedence in childhood which gradually develops to a global advantage in adulthood and then reduces in late adulthood, although task types, as well as other factors (discussed below) need to be considered.

Instead of using the terms 'processing abilities', 'preferences' or 'strategies', the term processing style will be used hereinafter, as it leaves open whether or not the processing includes a component of awareness or not (Pletzer et al., 2017).

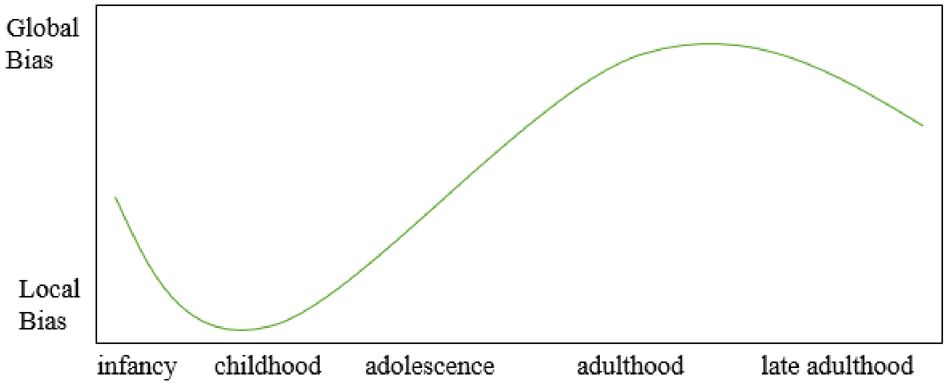


*Figure 2.4.* The suggested typical developmental trajectory of LGP preferences throughout the lifespan.

From the above discussion, it is apparent that general statements like 'children have a local bias' or 'adults show a GPE' are inappropriate when talking about LGP, FD/FI or CC. Although findings on a group level might point towards this direction, there are certainly interindividual differences between and within age groups, but also stimulus dependent factors that can influence study results. In addition, Pletzer et al. (2017) demonstrated in their study that there was no general tendency in individuals towards a particular style that would be independent of the task or stimuli. They concluded that the same participant might process some stimuli and tasks globally and others locally (which is in line with the above discussion of two separate continuums for local and global processing). Interindividual, stimulus and task-dependent aspects will be discussed below.

## 2.5 Interindividual differences influencing processing styles

Research suggests that processing styles vary between individuals stemming from different cultures, with different personality traits, sex, current mood and amount of autistic traits.

For example, intercultural research by Oishi et al. (2014) compared Japanese, American and Argentine children and adults in a range of LGP experiments. They found that Japanese individuals showed a less global processing style than those from the other two countries and this variation was already apparent from the age of four. However, all groups became more globally oriented with progression from childhood to adulthood. Nevertheless, in contrast to Oishi et al. (2014), McKone et al. (2010) found in a study comparing participants from different ethnic origins (in contrast to 'cultures') that East Asian

Australians (raised in Hong Kong, China, Singapore, Malaysia, Indonesia, Korea but also in Australia) exhibited a global preference, whereas Caucasian-Australians did not show global (or local) advantage in their tasks. McKone et al. argued that despite race usually not being mentioned in published work, it should be reported and potentially either kept homogenous or considered for grouping of participants in LGP research.

Further, interindividual differences, e.g. based on people's traits have been reported: Individuals showing tendencies of an obsessive-compulsive personality (Yovel, Revelle, & Mineka, 2005), as well as those with autistic-like traits (e.g.Grinter et al., 2009; Kasai & Murohashi, 2013; Reed, Lowe, & Everett, 2011) have been found to have a more local style. Moreover, differences between male and female sex have been found: Pletzer (2014, but not 2017) concluded from their study investigating sex differences that males orientate rather towards the global aspect of stimuli, whereas females tended to process them more locally. This finding is surprising given that the majority of ASD participants in research are usually male and exhibit a local bias (see also Section 3). Kimchi, Amishav, and Sulitzeanu-Kenan (2009) found no sex differences in processing biases but females showed more global interference in a local task compared to men.

Finally, a more global processing style has been reported to be related to positive mood, whereas negative mood was associated with increased local processing (Bianchi & Laurent, 2009, 2010; De Fockert & Cooper, 2014; Gasper, 2004; Gasper & Clore, 2002; Mottron, Dawson, Soulières, Hubert, & Burack, 2006). On the other hand, Baumann and Kuhl (2005) found a general cognitive flexibility accompanying positive mood leading to better perception of the non-default processing level. This would mean that in those individuals with a local processing preference, positive mood would improve global processing.

The influence of mood on LGP has been examined in pilot studies of this dissertation. For this objective, participants were asked to complete a local-global hierarchical figures task and two questionnaires: the Positive and Negative Affective Schedule (PANAS, Watson, Clark, & Tellegen, 1988) and the Dino-VAS (a child-friendly questionnaire with a visual analogue scale created for this study). However, the results showed no systematic effects of mood on the behavioural data of the participants. Thus, it was decided not to investigate this further in subsequent studies (see Appendix D.1 for further information).

### 2.5.1 The broader autism phenotype

The amount of autistic traits that individuals have varies in the typical and atypical populations and can be measured with questionnaires such as the Autism Spectrum Quotient (AQ, Baron-Cohen et al., 2001). TD with higher amounts of autistic traits (higher AQ scores, or the 'broader autism phenotype') have been reported to be faster in the EFT and to have poorer global motion and form thresholds than TD with lower AQ scores (Grinter et al., 2009). Moreover, Van Boxtel and Lu (2013) showed that TD with low AQ scores were automatically attracted to global motion information, whereas this was not the case for TD with higher AQ scores; the latter ones were, however, able to compensate global processing deficits by increased usage of local processing. Similarly, Happe et al. (2001) demonstrated that fathers of individuals with ASD, who belonged to the broader autism phenotype, showed a local processing style in CC tests. Another, more recent study exploring perception in participants with high and low AQ scores found reduced global processing of peripherally presented stimuli in the group with high AQ scores, but not those with low scores (Crewther & Crewther, 2014). However, the groups did not differ in global processing of centrally presented stimuli. Finally, Cribb, Olaithe, Di Lorenzo, Dunlop, and Maybery (2016) conducted a meta-analysis on 12 studies and examined whether and how AQ scores affected performance on the EFT. They found that studies using *extreme groups* (i.e. low vs high AQ scores, e.g. Grinter et al., 2009) consistently found superior performance in the EFT, whereas studies that examined AQ scores as a *continuous* variable, did not (possibly due to reduced statistical power). Nevertheless, overall, the findings demonstrate that the broader autism phenotype in TD is associated with an enhanced local processing style, similar to what has been reported in ASD (see Section 3). Thus, individuals with more autistic traits are likely to be located at the end of weaker central coherence / weak global coherence in Figure 2.2 and Figure 2.3 on page 32.

## 2.6 Stimulus and task aspects influencing processing styles

After exploring interindividual aspects of variations in LGP, next, stimulus- and task-dependent variations in LGP will be presented, including visual angle, stimulus density, presentation times, fill, stimulus category, attentional demand, and analysis methods.

### 2.6.1 Visual angle of local and global stimuli

Kimchi (1992) reviewed whether and how stimulus characteristics of hierarchical figures can influence the global precedence effect (GPE). They found, for example, that spatial frequency or size of stimuli influences processing styles. Blanca Mena (1992) found a GPE in stimuli extending over 3° visual angle (VA) but not in those with a diameter of 10° VA. Similarly, Lawson et al. (2002) reported a local precedence effect (LPE) in large stimuli (10°VA of the global form) but a GPE in smaller stimuli (2.5° VA), whereas Kinchla and Wolfe (1979) found GPE for stimuli under 7° VA and an LPE for those over 7° VA. However, other studies have shown that the GPE does not depend on the absolute size of the stimuli but the relative size compared to the set of stimuli present during that experiment. For example, Lamb and Robertson (1990) used a set of smaller stimuli (1.5°, 3°,4.5°, or 6° VA) and a larger set (3°,6°, 9°, or 12° VA) in separate blocks and showed that within both sets a global advantage was found in the relatively smallest stimuli, but a local advantage for the larger ones. However, this does not explain why a GPE is found in the majority of experimental designs that use only one stimulus size.

Related to relative size are the findings by Krakowski, Borst, Pineau, Houdé, and Poirel (2015) who used hierarchical stimuli with three levels (global, intermediate, local). They demonstrated that a processing advantage was present for the global but also intermediate level. Only the smallest elements were processed less efficiently. Similarly, Rijpkema, van Aalderen, Schwarzbach, and Verstraten (2007) also included three levels in their experiments and showed that reaction times (RTs) increased from global to middle to local; thus, the global advantage increased with increasing level of globality (although interference effects did not increase in the same way and were only present for the next neighbouring level).

Taken together, the evidence suggests that smaller hierarchical stimuli are more likely to be processed globally, whereas in larger stimuli local processing of the elements is more likely.

### 2.6.2 Stimulus density

Scherf et al. (2008) suggested in a priming study in which the number and size of local elements was manipulated (many smaller local elements vs few larger local elements) that the GPE is more prominent with many elements, whereas fewer elements lead to a local bias (see also Figure 2.5). Similar findings were already reported by Kimchi (1998) and LaGasse (1993). LaGasse, for example, showed that the GPE was more pronounced in denser stimuli made from many elements (e.g. a global square made out of 8 local squares) than in few element patterns (the same sized square made out of 4 local squares). Kimchi (1992) suggested that more dense local elements benefit the goodness of the global form and therefore facilitate its recognition, whereas less local elements make the global form less salient (see also Booth, 2006; Kimchi, 2014). It needs to be noted that it is not fully distinguishable from the above studies whether the found effects were due to the number, size or density of elements, as these are inevitably related variables.

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*Figure 2.5.* Stimulus dependent global or local advantages in hierarchical figures.
Based on (Kimchi, 1992; Kimchi, 1998; LaGasse, 1993; Scherf et al., 2008). Smilies indicate good and poor performance.

### 2.6.3 Stimulus presentation duration

In many experiments assessing LGP, the exposure duration of the stimuli is very long (> 1000ms) or even unlimited (e.g. Hayward et al., 2012; Ozonoff, Strayer, McMahon, & Filloux, 1994; Scherf et al., 2008), which could allow for both processing levels to be analysed before a response is given. Even if the participants are asked to respond as quickly as possible and therefore to their first percept, they might respond to what they perceived at a slightly later stage of processing, putting the reliability of the task design in question.

However, although stimulus presentation times do play a role (e.g. Andres & Fernandes, 2006; Paquet & Merikle, 1984) the general agreement is that global features in hierarchical stimuli have an advantage over local features. Paquet and Merikle (1984) presented Navon Figures to for 10, 40 or 100ms and asked participants to report the letter on the local or global level. The results showed a unidirectional global-to-local interference for durations of 10ms, but bidirectional interference for longer durations. Therefore, global precedence was reduced at longer stimulus durations and local processing improved. Similar findings were reported by Wang, Mottron, Berthiaume, and Dawson (2007). Andres and Fernandes (2006), however, showed that exposure duration did not affect global processing. However, interference in incongruent and facilitation in congruent trials differed between short and long exposure durations (here 17 vs 100ms) when the targets were local: facilitation was only found in the long trials. The authors concluded that interference relied on automatic early perceptual processes whereas facilitation relied on more conscious processes. Thus, the above studies suggest that global features of stimuli are processed earlier than local ones, an effect that is apparent already with very short stimulus presentation times.

### 2.6.4 Stimulus fill

Hübner and Kruse (2011) demonstrated in their first experiment that whether stimuli were outlined or filled-in influenced the GPE: They found a more pronounced global advantage with shorter RTs for the global and longer RTs for the local level when stimuli were outlined compared to filled-in. Different effects between outlined and filled in stimuli were also reported by List, Grabowecky, and Suzuki (2013). They examined level-priming (see Section 2.7.1) in filled-in vs. outlined geometrical hierarchical shapes. They found level-priming of global and local targets with outlines elements but not with filled-in stimuli. This puts the generalisability of findings from studies using different types of stimuli further into question.

### 2.6.5 Stimulus category

It has been found that hierarchical stimuli made up of letters lead to different experimental results than those made up of figures or shapes. For example, Keieta, Bedoin, Burack, and Lepore (2014) as well as Bedson and Turnbull (2002) found a left hemispheric dominance for local letters but not for local figures when presenting stimuli unilaterally. Pletzer et al. (2017) also reported different results for letters and shapes: A GPE was more pronounced with stimuli made out of letters compared to shapes (but only in the divided, not the selected attention task). Different results between letter and shapes as stimuli have also been reported by Gerlach and Krumborg (2014) and Wang, Li, Fang, Tian, and Liu (2012). Among other results, Gerlach and Krumborg (2014, and similarly Poirel, Pineau, & Mellet, 2008) demonstrated that a global-to-local interference effect was more pronounced when stimuli were letters compared to shapes. They suggest that letters and other written materials are suppressed more difficulty (as seen for example in the Stroop Effect, Stroop, 1992) than shapes/objects and therefore lead to higher inter-level interference in LGP tasks.

### 2.6.6 Attentional demand

Is has been shown that results from hierarchical figures tasks can vary depending on whether it is a divided attention (targets appearing on the local or global level) or selective attention task (targets appearing only on one (predefined) level). As mentioned above, Pletzer et al. (2017) demonstrated that a GPE was larger in adult participants in a selected attention task (when using letters but not when using shapes) than a divided attention task. Plaisted, Swettenham, and Rees (1999) examined children with and without ASD in a hierarchical task using letters, and found similar results in the divided and selective attention task for TD (global advantage) but not for ASD (global advantage in the selective, but local advantage in the divided attention tasks).

In divided attention tasks, local and global targets can alternate in consecutive trials, or the target level can be repeated in two consecutive trials. Thus, attention can sometimes remain focused on the global (or local) level; other times, it is required to switch to the opposite level. These processes can be described as level-priming and level-switch and will be discussed in the next section after the review of influences of analysis methods.

### 2.6.7 Analysis method

Gerlach and Krumborg (2014) conducted a study examining LGP in TD as well as a patient with prosopagnosia. They used their data in order to compare different LGP indices that have been implemented by other researchers in order to quantify global precedence and interference effects. The authors found that not only were those indices not related to each other, but some also had very poor or no reliability (split-half correlations n.s. or very low). Unsurprisingly, studies using different indices might thus lead to different results with different conclusions (even if the same data were analysed).

## 2.7 Priming of local and global processing

Priming describes the phenomenon where reactions to a target occur faster (or more accurately) when the target is following a stimulus (the *prime*) which is associated with the target in a certain manner. In the case of hierarchical figures, priming could be achieved by *identity/repetition priming* (where the priming stimulus is exactly the same as the next target stimulus) or *level-priming* (where the targets' levels were the same in the prime and primed stimulus). Priming effects (PE) are the difference between the RTs to the target with and without congruent priming {cf. Forster, Mohan, & Hector, 2003, see Figure 2.6}. Wiggs and Martin (1998) concluded from their review that priming effects remain relatively stable from the age of 3 to 80 years, even if performance (accuracy, RTs) on tasks vary between ages.

Priming of processing levels has been examined within the same modality (visual domain: e.g. Hayward et al., 2012; Keieta et al., 2014; List et al., 2013; Prieto & Montoro, 2015; Robertson, 1996; auditory domain: Justus & List, 2005), but also across modalities (Forster, 2011; Gao, Flevaris, Robertson, & Bentin, 2011).

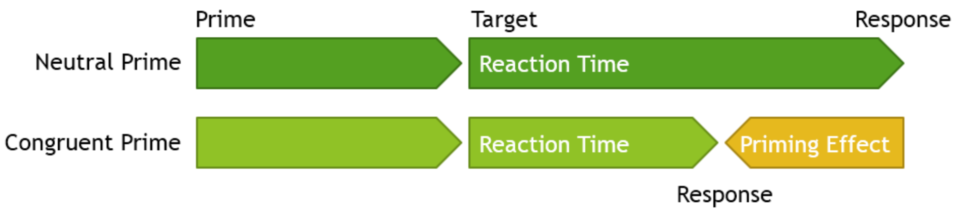


*Figure 2.6.* The relationship between prime (neutral or congruent), target, RT and priming effect. A congruent prime prepares for the target leading to reduced RTs compared to when a neutral prime was presented. A priming effect (PE) can be measured.

### 2.7.1 Level-priming and Level-switching

*Level-priming* occurs when two subsequent targets are on the same level of the stimuli (e.g. global) and it is the opposite of a *level-switch* (subsequent targets are on different levels and therefore a switch from e.g. global to the local level is necessary).

Researchers demonstrated that responses to a target stimuli were faster if the preceding target was on the same level (level-priming, or level-readiness as called by Ward, 1982) compared to when a *level-switch* needed to occur (Filoteo, Friedrich, & Stricker, 2001; Hayward et al., 2012; Hubner, 1997, 2000; Huizinga et al., 2010; Lamb & Yund, 1996, 2000; Prieto & Montoro, 2015; Robertson, 1996; Shedden, Marsman, Paul, & Nelson, 2003; Ward, 1982). They even found robust level-priming effects when the stimuli changed their location (e.g. from left to right visual field). This indicates that participants "tuned in" to the specific processing level and that there was a cost associated with switching from one level to the other.

### 2.7.2 Explicit and implicit manipulation

Priming does not necessarily have to be induced by specific priming stimuli. Research has shown that a global or local processing style can be induced or primed by the experimental design and instruction given to the participants. For example, Hayward et al. (2012), Plaisted et al. (1999), and Pletzer et al. (2017) instructed participants to focus only on the local or global level in their selective attention tasks which lead to faster RTs compared to the respective level in the divided attention task.

This priming by instruction can be classed as an explicit manipulation of the attended processing level as it explicitly influences the expectations of where targets will occur. A more implicit manipulation is also possible; for example, Iarocci, Burack, Shore, Mottron, and Enns (2006) and Hayward et al. (2012) demonstrated this by manipulating the frequencies (contingencies) of local and global targets in a given block. Hayward et al. (2012) implemented seven test blocks that differed in the proportion of local and global trials within each block: 0:100, 20:80, 40:60, 50:50, 60:40, 80:20 or 100:0. They found a GPE overall, faster RTs, and higher accuracy with higher contingencies. This effect indicates usage of implicit information about the contingency in order to allocate more attention to the local or global level (whichever is more frequent) and will hereafter be called the *contingency effect* (CE). Hayward et al.'s (2012) task was adapted for this dissertation and used in the studies PECOG and VISTA studies which aimed to examine the flexibility of the perception biases/processing styles in cross-sectional TD and ASD samples.

## 2.8 Summary of Chapter 2

This chapter reviewed the current state of research regarding LGP in TD, interindividual-/developmental-, stimulus-, and task-dependent aspects of LGP.

As has been made apparent, LGP has been researched extensively for decades; nevertheless, findings are still inconclusive. Some of the findings can be accounted for by differences between individuals (age, autistic traits, mood effects), others by variations in the tasks (used stimuli, attentional demand), or the analysis methods. Nevertheless, there remain inconsistencies and open questions. This fact has motivated the PECOG study in Chapter 7 that consisted of three experiments that built upon each other. The first experiment (task: STIMMIX) included a mix of hierarchical stimuli that differed by shape (e.g. diamond, squares, triangles), filling (outlined, filled) and size (large, small) aiming to examine whether the GPE could be found in all those stimulus variations and what influence the manipulated stimulus characteristics had on the GPE in a sample of TD students. For the next two experiments of the PECOG study, the tasks CONTI and CONTMASK were created in order to examine the flexibility of the GPE (including effects of level- and identify priming) and the effect of reduced processing times on LGP. In Chapter 8.1, developmental aspects of LGP and its flexibility were addressed in a study with a cross-sectional TD sample from the age of 7 (VISTA study). Chapter 8.2, on the other hand, compared this normative sample to a cross-sectional sample of individuals diagnosed with ASD.

The current knowledge base regarding LGP in ASD will be addressed in the next chapter.

# 3 Local and Global Processing in ASD

## 3.1 Chapter overview

This chapter gives an overview of LGP in individuals with ASD. First, two popular theories of LGP in ASD will be introduced and discussed, followed by elaborations of various interindividual and task-related factors that might influence LGP in ASD. Lastly, findings will be presented about whether or not processing biases are domain-overarching.

LGP has not only been extensively researched in TD individuals but is also of interest in those that deviate from typical development, e.g. individuals with ASD. For a long time, the dominant view was that individuals with ASD are impaired in perceiving the global aspect of a stimulus and show normal or enhanced local perception compared to TD individuals (e.g. Frith, 1989). However, further research has shown that the matter is not as simple as increasing amounts of inconsistent findings occurred. Consequently, a variety of theories have been developed trying to explain the nature of LGP in ASD. Amongst the most well-known theories in that domain are the Weak Central Coherence Theory (WCC) and Executive Dysfunction Theory which will be introduced and discussed in the following sections.

## 3.2 Explaining atypical processing in ASD

### 3.2.1 Weak central coherence theory

Uta Frith (Frith, 1989) developed the Weak Central Coherence (WCC) Theory aiming to explain the phenomenon of detailed focused processing in ASD. According to Frith individuals with ASD show impaired global processing and intact local processing, as becomes apparent e.g. in their performance in visual tests like the Embedded Figures Test (EFT, Witkin et al., 1971) or Block Design Task (BD, Wechsler, 1998).

Central coherence (CC) is understood as the tendency to process information in its given context and to draw diverse information together in order to construct higher-level meaning {e.g. Frith & Happe, 1994, see also Section 2.2}. The concept of CC is therefore closely related to Navon's global precedence effect (1977). According to Frith's original account (1989) individuals with ASD show impaired global processing and therefore reduced global interference (they are, therefore, for example, less distracted by the whole picture in the EFT), and intact local processing (they can detect the target form effortlessly).

However, the WCC theory has been modified throughout the years in order to incorporate later findings (e.g. Happe & Frith, 2006): in the updated version, instead of a deficit in global processing, it is thought that individuals with ASD show a local processing *preference* (in contrast to TD who have a global processing preference). WCC is therefore seen as a *cognitive style* and not an impairment, suggesting that individuals with ASD tend to process stimuli locally although they would be able to process them globally (Happe, 1999, but Booth & Happe, 2016, concluded that global integration was, in fact, reduced in ASD). In this regard, the WCC has aligned with the Enhanced Perceptual Functioning (EPF) Theory which implies enhanced local processing with intact global processing (Mottron & Burack, 2001; Mottron et al., 2006). In contrast to WCC, the EPF theory states that local processing is mandatory and not optional in ASD. WCC can be classed as a cognitive and EPF as a neural theory for visual processing in ASD (Simmons et al., 2009) and results from cognitive studies are often not able to differentiate between WCC and EPF as the accounts make similar predictions regarding the outcome: enhanced local processing with intact global processing (cf. Pellicano, 2012).

Happe and colleagues (Happe & Frith, 2006; Happe et al., 2006) stress that WCC cannot explain all symptoms in ASD like e.g. social deficits, but co-occurs with them (This is in contrast to Frith's original formulation from 1989). Therefore, other theories like the Theory of Mind (ToM) Deficit Account and Executive Dysfunction Theory would be suitable to explain other aspects of ASD (The ToM will not be discussed in this dissertation).

### 3.2.2 Critique of the WCC theory

The original WCC account (Frith, 1989) stated a reciprocal relationship between LGP with a global processing deficit which has since been repeatedly criticised over the years. Not surprisingly, the theory has been modified and updated throughout the years in order to fit newer research findings (e.g. Happe

& Frith, 2006); but in this way, it assimilated other theories like, for example, the EPF account (Mottron, Peretz, & Menard, 2000).

Pellicano (2012, p. 14) critiqued the claim that WCC would be "*universal in, and specific to, autism*". Many studies either failed to show WCC in ASD or demonstrated that only a proportion of individuals with ASD showed WCC performance (e.g.Caron, Mottron, Berthiaume, & Dawson, 2006, pp. only 42% of ASD individuals peaked in the Block Design task, vs 42% of TD individuals; also Booth, 2006), indicating that WCC is not universal in ASD. Secondly, WCC is not specific to ASD: Atypical LGP has also been reported in other patient groups, e.g. schizophrenia (Coleman et al., 2009), prosopagnosia (Duchaine, Yovel, & Nakayama, 2007), Williams syndrome (Deruelle, Schon, Rondan, & Mancini, 2005; Godbee & Porter, 2013), Dyspraxia (O'Brien, Spencer, Atkinson, Braddick, & Wattam-Bell, 2002), blindness (Puspitawati, Jebrane, & Vinter, 2013), ADHD (Song & Hakoda, 2012; Song & Hakoda, 2015), and dyslexia (Conlon, Lilleskaret, Wright, & Stuksrud, 2013; Gori, Cecchini, Bigoni, Molteni, & Facoetti, 2014; Ziegler, Pech-Georgel, George, & Foxton, 2012).

Although Happe and Frith (2006) state that WCC should account for lower (perceptual, visuo-spatial) and higher (verbal-semantic) level systems, empirical evidence for this is limited according to Pellicano (2012). She suggested that maybe WCC is limited to the lower systems, but critiqued that even within the lower level, evidence for intercorrelations between central coherence tasks was scarce (cf. Milne & Szczerbinski, 2009). However, despite her reservations, there has been evidence for higher verbal-semantic WCC in Autism (see Chapter 4).

Lastly, the WCC claims that other psychological functions are independent of central coherence (CC). There has been mixed evidence regarding this statement, with some studies showing associations between WCC and ToM or executive functions (EF) and others not findings relationships between these psychological functions. For example, Pellicano, Maybery, Durkin, and Maley (2006) demonstrated that WCC was not related to ToM but EF in children with ASD, whereas Pellicano (2010) found that CC predicted ToM skills three years later.

As evident, the WCC theory has met with valid criticism, and alternatives have been proposed, for example, the Executive Dysfunction Theory.

### 3.2.3 The executive dysfunction theory

The executive dysfunction theory (Ozonoff et al., 1991) was originally proposed in an attempt to explain the ASD symptoms of repetitive behaviours and restricted interests. Studies showed consistent impairments of Executive Functions (EFs) in individuals with ASD regarding working memory, cognitive flexibility, planning, attention shifting, and response inhibition (for reviews and meta-analyses see Craig et al., 2016; Demetriou et al., 2017; Geurts, van den Bergh, & Ruzzano, 2014; Hill, 2004; Kercood, Grskovic, Banda, & Begeske, 2014; O'Hearn, Asato, Ordaz, & Luna, 2008). Happe and Frith (2006, p. 17) related EF to central coherence and defined EF as:

> *…an umbrella term covering a range of higher-order cognitive abilities necessary for flexible and adaptive behaviour in the service of novel goals. As such, executive function might be seen to encompass the processing of information in context for global meaning, i.e. central coherence.*

The authors further elaborate that findings supporting the WCC theory might potentially be explained by limited EF, e.g. the ability to shift between processing levels, poorer working memory performance which biases a more local processing approach, and reduced planning abilities which could impair performance in novel tasks and lead to a piece-meal approach. However, Booth, Charlton, Hughes, and Happe (2003) and Booth and Happé (2010) concluded from their studies with TD, ASD and ADHD children, that WCC and EF were not related, and thus, Happe and Frith (2006) reject the idea that a local bias and, with that, WCC in ASD was due to an executive dysfunction.

## 3.3 Mixed evidence regarding atypical processing in ASD

Various theories were developed to explain why ASD might have atypical LGP; however, reviews and meta-analyses have shown that the case of processing atypicality is not as clear-cut. This will be discussed in the following sections.

Muth, Honekopp, and Falter (2014) conducted a meta-analysis examining overall effect sizes for group differences between TD and ASD in the EFT, BD, Mental Rotation and Navon task. The analysis of 35 studies revealed that in the EFT participants with ASD showed on average a better performance compared to TD. However, it was stressed that there was high heterogeneity in the data, the group differences were small and disappeared (and heterogeneity reduced) when removing four studies that were outliers (in that they showed atypical processing): Brosnan, Gwilliam, and Walker (2012), Pellicano, Gibson, Maybery, Durkin, and Badcock (2005), Pellicano et al. (2006) and Shah and Frith (1993). Muth et al. (2014) further elaborated the meta-analysis results of 24 studies including the BD test, and again report only small group differences and high heterogeneity in the data. When analysing studies involving hierarchical figures, they found once more, that group differences between TD and ASD were overall not large: Seven studies showed that groups with ASD showed a small tendency of local precedence (compared to global precedence in TD) when given free choice. When combining four divided and nine selective attention studies, Muth et al. discovered a small effect size for the difference between TD and ASD regarding the strength of the global advantage. The difference between ASD and TD processing, therefore, does not seem to be as pronounced as often assumed. Overall, the authors suggest that the large heterogeneity in results might mainly be due to the heterogeneity of the autism spectrum and not due to IQ or age effects. It was concluded that "*the assumption that participants with ASD generally excel and perform exceptionally in visuo-spatial tasks is incorrect"* (Muth, 2014, p. 3261) which would oppose both, the WCC and EPF theory.

In contrast to Muth et al.'s (2014) review, Happe and Frith's (2006) review of over 50 studies had led to different results: They concluded that a local bias in ASD was robust, while global processing yielded mixed results. However, contrary to Muth et al., Happe and Frith had a wider range of studies in their review and included children and adult studies dealing with language processing, visual illusions, drawing, face processing, visual search, pitch/music processing and others. Nevertheless, Happe's and the cited references' results need to be regarded with caution, as there is no scientific consensus of how exactly LGP are defined, for example, in music/pitch perception or language processing {see meta-analysis by Van der Hallen, Evers, Brewaeys, Van den Noortgate, & Wagemans, 2015, and also Section

4.4}. Even in visual processing, tasks that presumably measure LGP have not been found to measure the same construct (Factor-analysis by Milne & Szczerbinski, 2009, see also Section 3.4.3).

Inconsistent findings could potentially be attributed to the researchers' definition of local and global processing, the sample composition (age, severity of ASD, subgroups) but also other factors like the task at hand (task type, attentional demand, and wording; see also elaborations in Sections 2.5 and 2.6). The samples of individuals with ASD vary largely across studies, with some studies examining the lower end of the spectrum (e.g. Heaton, Hudry, Ludlow, & Hill, 2008; Maljaars, Noens, Scholte, Verpoorten, & van Berckelaer-Onnes, 2011), and others examining individuals from the higher end with AS or HFA (e.g. Jolliffe & Baron-Cohen, 2001a, 2001b); some studies including children, others adolescents or adults (Plaisted et al., 1999). Similar to the variation of processing preferences in TD with more or less autistic traits, processing could vary across the ASD spectrum. For example, Jolliffe and Baron-Cohen (1999) compared individuals with HFA and AS and showed significant differences (in local-global language tasks) between those two high-functioning groups. Similarly, processing styles in ASD could change across the life-span, as they do for TD (see Section 2.4).

The next sections will go into potential influence on LGP in more detail.

## 3.4 Influences on local and global performance in ASD

### 3.4.1 Developmental aspects

Earlier in Section 2.4, it was discussed that in TD, individuation of many small and grouping of few large elements developed with age. Children were good in processing global features of hierarchical stimuli by grouping many small elements, but they struggled with the individuation of many small local elements. On the other hand, they showed good performance in local processing of few large elements vs. reduced global performance when grouping those elements (Kimchi, 1998; LaGasse, 1993; Scherf et al., 2008).

Potentially, performance in ASD and TD children could be similar, but there might be no developmental improvement in ASD and therefore different performance of ASD and TD adults. Scherf et al. (2008)

assessed not only TD but also participants with HFA. Compared to TD, participants with HFA showed a consistently faster performance regarding local processing across age groups. However, they did not gain as efficient global processing with age as TD did (in the many elements task). A recent study found that TD children reached adult-like performance in a global coherent motion task at the age of 8-11 years, whilst in ASD mature motion sensitivity developed only in adolescents (Van Eylen, Boets, Steyaert, Wagemans, & Noens, 2018).

The EFT has been used in many studies, some of which included children (e.g. Morgan, Maybery, & Durkin, 2003), mean chronological age (CA) 4 years), adolescents (Ropar & Mitchell, 2001, mean CA 12-14 years; Shah & Frith, 1983, mean CA 13 years), or adults (Jolliffe & Baron-Cohen 1999, mean CA 28-31 years). They showed that individuals with ASD were faster and/or more accurate in the EFT than their TD peers indicating reduced global interference/increased local processing. Edgin and Pennington (2005) assessed a cross-sectional sample aged 7 to 17 years on the EFT and concluded that although there appeared to be a local processing advantage in younger children with ASD compared to TD, this difference equalled out with increased age. Muth et al. (2014) found in their systematic review that the data from EFT studies was very heterogeneous and ranged from significantly better performance in ASD (d = 2.36, Pellicano et al., 2006), to better performance in TD (d = -.078, Burnette et al., 2005). These results could not be explained by age or IQ differences.

Studies using hierarchical Navon figure had similarly mixed results: in adolescents, similar performance was reported in ASD and TD (e.g. Mottron, Burack, Iarocci, Belleville, & Enns, 2003, mean CA 16 years) or even a global advantage only in ASD (Mottron, Burack, Stauder, & Robaey, 1999, mean CA 15 years). Younger children, on the other hand, were found to show comparable performances in ASD and TD in some studies (e.g. Ozonoff et al., 1994, mean CA 12 years; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2000, mean CA 10-12 years), but less global advantage in ASD children in other studies (Deruelle et al., 2005, mean CA 7-9 years; Koldewyn, Jiang, Weigelt, & Kanwisher, 2013, mean CA 8-9 years; Bernardino et al., 2012, mean CA 12-15 years). Plaisted et al. (1999) demonstrated no group differences in ASD and TD children (mean CA 10 years) in a selective attention task, but significant differences (no global advantage in ASD) in the divided attention task. Similarly, Koldewyn et al. (2013) found a local processing preference in ASD with intact global processing abilities.

In adults, the global advantage has mainly been reported to be reduced in ASD compared to TD (e.g. Behrmann et al., 2006; Bölte, Holtmann, Poustka, Scheurich, & Schmidt, 2007; Katagiri et al., 2013; Rondan & Deruelle, 2007).

Despite these seemingly varied results across age groups, Muth et al. (2014) as well as Van der Hallen, Evers, Brewaeys, Van den Noortgate, and Wagemans (2015) concluded from their meta-analyses that age does not play a significant role when assessing LGP in TD and ASD. However, it appears that direct comparisons of different age groups using the same experimental design with hierarchical figures are scarce (except e.g. Scherf et al., 2009; Scherf et al., 2008). This gap in the literature was one of the issues addressed in this dissertation.

### 3.4.2 Macrocephaly

It has been proposed that there are subgroups of individuals with ASD who differ in the extent of CC. For example, White, O'Reilly, and Frith (2009) found that head size covaried with the ability to switch from local to global processing in ASD, and O'Reilly, Thiebaut, and White (2013) demonstrated that a local processing bias was more pronounced in autistic (but not TD) individuals with macrocephaly ("bigger brains"). One hypothesis is that bigger brains in ASD are due to a lack of synaptic pruning (e.g. C. Frith, 2003; Happe, 1999). In TD, the amount of synapses in the brain increases during the first years after birth and then starts to decrease until adulthood (Huttenlocher, 1979). If this process is impaired this could lead to more brain volume and less efficient connection between brain areas which could be related to reduced global processing.

Deutsch and Joseph (2003) and Tager-Flusberg and Joseph (2003) had explored the relationship between head circumference (and brain volume) in ASD and verbal/non-verbal IQ discrepancies and found that larger heads were associated with increased NVP (compared to VP) scores. High NVP is often tested by the BD or EFT -- measures associated with enhanced local processing skills.

Based on these findings, head circumference was measured in the TD participants of the pilot studies of this dissertation. However, no significant relationships were found between head circumference, and LGP biases (see Appendix D.2 for more details).

### 3.4.3 Task type

As already made apparent, LGP has been examined with many different tasks, not just hierarchical stimuli. Other tasks often utilised for assessing LGP styles involve, for example, optical illusions (e.g. Kanizsa illusory contours, Nayar et al., 2015), global vs local motion detection (e.g. Bex & Dakin, 2002), the EFT (e.g. Ropar & Mitchell, 2001), drawing tasks (e.g. Tsatsanis et al., 2011), visual search tasks (Iarocci et al., 2006), discrimination tasks (e.g. Plaisted, Saksida, Alcantara, & Weisblatt, 2003), the BD task (e.g. Shah & Frith, 1993), or attentional blink paradigms (e.g. Lawson et al., 1998). However, Milne and Szczerbinski (2009) have shown in their factor-analysis of common tasks which all supposed to be assessing LGP, that they are in fact measuring slightly different aspects: Seven factors have been identified, e.g. disembedding, global bias, cognitive flexibility, perceptual speed. Potentially, some tasks are more likely to elicit or detect a GPE than others. In addition, Chamberlain et al. (2017) also demonstrated that correlations between performance on a (new) EFT and a hierarchical figures task was low. The question arises therefore how comparable studies are that use different tasks or those who use the same task (hierarchical figures) but different stimulus sizes/spatial frequencies, different shapes or letters. As was elaborated in Section 2.6, such stimulus variations can influence the outcome of an LGP study. For example, List et al. (2013) demonstrated in their study that even small stimulus variations like the stimuli being filled in or outlined already made a difference regarding the outcome of the study.

### 3.4.4 Attentional demand of the task

It has been argued that the attentional demand plays an important role in processing in ASD (like also in TD, see Section 2.6.6): For example, Plaisted et al. (1999) reported that tasks requiring divided attention result in local precedence in children with ASD, whereas in tasks that require selective attention, individuals with ASD were likely to show a typical GPE. However, Hayward et al. (2012) examined adolescents and young adults with HFA in divided and selective attention tasks and had different results: They did not find local precedence for ASD neither in their selective nor divided attention task; global precedence was displayed in TD and ASD in both tasks.

Nevertheless, Muth et al. (2014) concluded in their systematic review that the data suggest that in both task types (divided and selective attention tasks), the global advantage is smaller in ASD than TD; however, this was not as reliably found in selective attention tasks.

### 3.4.5 Wording of the task

It has further been shown that individuals with ASD are rather specific about the wording of the task. For example, they tend to respond differently when asked whether the two circles in the Ebbinghaus Illusions (also sometimes called Titchener Circles: two same-sized circles that are surrounded either by larger or smaller circles in a flower petal arrangement) *are* the same or *appear* to be the same (Scott, Brosnan, & Wheelwright, submitted, as cited in Happe & Frith, 2006). They might answer negatively regarding the appearance but positive to whether the circles are the same. Small differences or irregularities in instructions could therefore potentially lead to different results.

### 3.4.6 Local advantage as a possible splinter skill in ASD

Heaton, Williams, Cummins, and Happe (2008) examined pitch processing in 33 adolescents with ASD and 35 TD controls and expected to find enhanced pitch processing (local processing) in the ASD group. However, only around 10% of their ASD sample (n = 3) did show enhanced pitch processing. From those 3 participants, 2 also showed peak performances in the Block Design task, whereas 4 from the remaining ASD sample peaked at Block Design but not in pitch processing. This leads to two possibilities: Firstly, local processing biases (and therefore enhanced local processing) might be found only in a subgroup of individuals with ASD, whereas the bigger percentage would show comparable processing to TD controls; Secondly, even in this subgroup, enhanced local processing might be found in different domains in different individuals – sometimes domain specific, sometimes domain-overlapping. Other researchers have also demonstrated that only a percentage of participants with ASD showed reduced global or enhanced local processing (Booth, 2006; O'Reilly et al., 2013).

## 3.5 Are processing styles domain-overarching?

So far, the research discussed here has nearly exclusively concentrated on processing styles in vision. However, LGP has been also examined in the auditory domain (see for reviews: Haesen, Boets, & Wagemans, 2011; O'Connor, 2012; Ouimet, Foster, Tryfon, Hyde, & Annals, 2012), tactile domain (e.g. Puts, Edden, Wodka, Mostofsky, & Tommerdahl, 2013; Tommerdahl, Tannan, Cascio, Baranek, & Whitsel, 2007), olfactory and gustatory domain (not that extensively, e.g. Forster, 2011; Förster & Denzler, 2012) and in language (see more in Chapter 4). The question arises whether processing styles are domain specific or domain overlapping. There has been some evidence suggesting that individuals who have a certain processing style in one domain will also exhibit it in another domain {but see Heaton, Williams, Cummins, & Happe, 2008, Section 3.4.6 and also below}.

For example, Bouvet, Rousset, Valdois, and Donnadieu (2011) examined TD in LGP in the domains of vision (hierarchical figures) and audition (global: low temporal frequencies/slow changes; local: high temporal frequency/speed). They found that those TD individuals who showed more global advantage in vision also had it in audition, and, therefore, similar cognitive styles across both modalities. It is, thus, possible that individuals with ASD would show comparable processing styles across domains, too. However, consequently, it could be questioned why savant skills in ASD (which are thought to be at least partly based on extraordinary local processing; Happe, 1999) are usually limited to a specific domain, e.g. music, calculations, or language, and not overarching domains. Perhaps, savants could actually be skilled across more domains but are limited to one domain due to their restricted and narrow interests.

Foxton et al. (2003) report that in TD, reading skills and phonological abilities were correlated with auditory perception. More specifically, higher language skills were associated with a better perception of the global structure of a melody (pitch patterns) but not the local structure (absolute pitch values). Potentially, if individuals with ASD have diminished global auditory perception, this might be correlated to their reading and other language performance.

In the previously described study of Heaton, Hudry, et al. (2008) it was found that only some individuals with ASD (3 out of 33) showed enhanced local processing in audition (pitch perception), and some of those also showed enhanced processing in vision (block design). Heaton et al. further established that in this subgroup with increased local auditory processing, the vocabulary scores were lower than the overall ASD mean, and there was a large discrepancy between verbal and non-verbal performance scores in two out of three participants in the subgroup. This suggests that enhanced local processing in one domain could impact negatively (regarding language) or positively (regarding visual local perception) in other domains. It further suggests that 'domain-general cognitive models of autism' might not be suitable for explaining findings of enhanced local processing in a specific domain.

## 3.6 Summary of Chapter 3

This chapter reviewed the current literature regarding LGP in ASD, including theories that were proposed to explain LGP like the weak central coherence theory (WCC) or enhanced perceptual functioning theory (EPF). As apparent from the discussion, however, the evidence for WCC or EPF is mixed and, like has also already been discussed in Chapter 2 regarding TD, interindividual and task-dependent factors outside LGP itself can influence the outcome of a given study.

In the VISTA study of this dissertation (Chapter 8), LGP in vision was assessed in TD and ASD in order clarify some of the open questions in this field, e.g. whether or not participants with ASD are more likely to have a local advantage compared to TD, what the developmental trajectories are, whether global processing is impaired or intact in ASD, but also how flexible TD and ASD are regarding processing biases and switching between levels.

Aside from vision, LGP in language was also central for this project. LGP in language, especially in individuals with ASD will be covered in the next chapter.

# 4 Local and global language processing

## 4.1 Chapter overview

In this chapter the current state of research regarding local and global language processing (LGLP), especially in ASD, will be reviewed and discussed. It includes elaborations of how local and global processing levels are represented in language, what research outcomes have been reported when using various more or less local and global tasks, and a discussion on explanatory accounts and potential reasons for mixed results.

## 4.2 Processing levels in typical development

In her "Less is More" hypothesis, Newport (1990) describes how the maturational limitations of a child's processing abilities facilitate language learning. According to Newport, language processing in children is focused on elements (e.g. morphemes) and their componential analysis. This helps children to perceive, analyse and therefore learn components of complex language more easily (in a piece-meal bottom-up fashion). Later on, during the development until adulthood, these 'limited abilities' are extended and the individual improves on integration and perception of complex wholes like whole words and sentence structures. However, in the same time, due to the different ways linguistic input is perceived, stored and processed in adults compared to children, the ability to perform such detailed morphological analyses that children do is unlearned (as can be seen in adult second language learners who rarely achieve full native proficiency). It can be therefore deducted that language learning starts in children with local processing methods which later transform into a global processing approach.

The previously mentioned study, Smith, Yu, and Pereira (2011, see Section 2.4) had demonstrated a local visual perception style in children aged around 1.5 years with a focus on single objects and its fragmented features. According to Smith (2009) this perception style changes a few months later towards object recognition based on geometrical and 3D-shapes, which facilitates object-name learning and categorisation and is thereby associated with language development. Vulchanova, Talcott, Vulchanov, and Stankova (2012) proposed that this object driven perception is *"analogous to the detail-focused bias associated with ASD, and can therefore also help explain some of the mysteries surrounding language acquisition"* (p. 15).

Together, the above literature suggests that the typical developmental trajectories if LGLP go from a more local processing style in childhood to a global processing style in adulthood which is equivalent and potentially linked to the often reported developmental trajectory of visual processing styles (see Chapter 2.4).

## 4.3 Language abilities in ASD

This section will only give a very short overview of language skills in individuals with ASD, as they will be elaborated in more detail in the following sections.

A deficit in social communication and interaction is one of two major symptoms that are reviewed during the diagnostic process of ASD (DSM-5, American Psychiatric Association, 2013). However, language competence in ASD can vary from nearly intact (like in AS) to non-existent (non-verbal, low functioning autism). Tager-Flusberg and Joseph (2003) describe that the pattern of performance in the verbally impaired subtype of ASD overlaps with that of children diagnosed with Specific Language Impairment (SLI).

Helland (2014) compared AS and SLI participants on the Child Communication Checklist (CCC, Bishop, 2003) and demonstrated that AS scored similar to SLI on the scales semantics and coherence but high on speech and syntax scales. They further showed poorer performance on the pragmatic composite score in AS which includes the subscales inappropriate initiation, stereotyped language, nonverbal communication, and use of context (although AS and SLI scored similar regarding use of context), indicating that these are deficits specific to AS/ASD. The same research group (Helland, Biringer, Helland, & Heimann, 2012) also compared AS and ADHD and found equivalent (poor) performances for both groups on most CCC scales, except for the pragmatic subscales stereotyped language and nonverbal communication where AS was more impaired than ADHD. Both groups scored comparably to TD on speech and syntax scales. Thus, although participants from those clinical groups showed similar communication skills, pragmatic competencies were only affected in AS. In contrast to Helland's findings, however, Geurts et al. (2004) demonstrated that both, individuals with HFA and ADHD had pragmatic difficulties compared to TD, although those of the HFA group were more pronounced. HFA also had poorer scores in speech and syntax compared to ADHD and TD.

In general, the consensus regarding language skills in ASD is that pragmatic language and discourse are impaired in ASD, even in those individuals where structural language is intact (Helland, 2014; Helland et al., 2012; Tager-Flusberg & Joseph, 2003; Vulchanova, Talcott, Vulchanov, & Stankova, 2012; Vulchanova, Talcott, Vulchanov, Stankova, & Eshuis, 2012).

## 4.4 Local and global aspects of language

According to Vulchanova, Talcott, Vulchanov, Stankova, et al. (2012), structural aspects of language (including morphology, phrasal syntax and other simple grammar) can be classed as *local*. However, pragmatic language aspects ("*the ability to process language beyond the literal interpretation of individual words*" p. 586) require higher processing demands and are *global.* Global processing thus entails semantic interpretation, inferencing based on context, text comprehension, higher-order grammar (e.g. use of articles), the interface between grammar and semantic (e.g. aspectual categories of the verb), the use and understanding of figurative language (metaphors and idioms) but also pragmatic information conveyed by prosody and intonation, and the integration of this nonverbal information with verbal information.

In this context, Jolliffe and Baron-Cohen (1999, p. 150) introduced the term *local coherence.* They described local as being "*information which is in short-term or working memory at the same time (usually between one to three sentence)"* whereas global involves larger chunks of information (five or more sentences) that cannot be held in short-term or working memory at the same time. According to this definition, tasks often employed to test global processing in ASD (e.g. the homograph reading task, see below) would therefore actually rather test *local* aspects or local coherence, instead of global ones.

Happe and Frith (2006) distinguish the term of local coherence as an alternative to "*truly configural global processing*" (p. 14), as it can be based, for example, on a simple chaining technique (i.e. item-to-item processing) or on connecting information in narrow domains (intra-domain coherence). For instance, arranging pictures in the Wechsler Picture Arrangement test (Wechsler, 1998, 2004), could be done either by utilising *global coherenc*e (understanding the overall story and arranging the pictures accordingly) or by utilising *local coherence* (linking each picture to the next one without appreciating the overall gist of the story).

In the following subsections, studies will be reviewed that investigated those local and global aspects of language processing, starting with local aspects (Section 4.4.1), local coherence (Section 4.4.2), lastly global processing (Section 4.4.3) and global coherence (Section 4.4.4; see overview in Figure 4.1).

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*Figure 4.1.* Illustration of the continuum of local and global aspects of language processing based on presented studies
(Happe & Frith, 2006; Jolliffe & Baron-Cohen, 1999; Vulchanova, Talcott, Vulchanov, & Stankova, 2012; Vulchanova, Talcott, Vulchanov, Stankova, et al., 2012).

### 4.4.1 Local Processing: Lexicon, ambiguous words, grammar and morphology

Vulchanova and colleagues have conducted two thorough case-studies into language processing in language talented individuals with ASD (Vulchanova, Talcott, Vulchanov, & Stankova, 2012; Vulchanova, Talcott, Vulchanov, Stankova, et al., 2012). They demonstrated that local aspects of language like lexicon/vocabulary, nominal and agreement morphology (Vulchanova, Talcott, Vulchanov, & Stankova, 2012), compounding, agreement, and semantic composition (Vulchanova, Talcott, Vulchanov, Stankova, et al., 2012) were intact or even superior, whereas more complex grammar, semantic integration, global inferencing and figurative language (which all need more global processing) were weak. Vulchanova et al. explain their findings by referring to the WCC theory. Their conclusions were consistent with other research that described individuals with AS as "*grammar machines, capable of crunching a morphological system as complex (and irregular) as that of Finnish*" (Niemi, Otsa, Evtyukova, Lehtoaro, & Niemi, 2010; Otsa, Evtyukova, Lehtoaro, Niemi, & Niemi, 2009); both as cited in Vulchanova, et al., 2012a, p. 24).

Similarly, Frith and Snowling (1983) had demonstrated that children with ASD were comparable to controls in single word reading (regular/irregular words and non-words) and as expected for their reading age (RA). They capably used a phonological and lexical strategy, had normal access to lexical semantics, differentiated between concrete and abstract words, showed a normal Stroop interference effect and were sensitive to syntactic constraints. The authors concluded that the syntactic and phonological development in ASD is likely to be delayed although not deviant. Frith and Snowling further report in this study, that ASD children failed to read for meaning, i.e. to use the semantic context of a sentence in order to find the correct pronunciation for ambiguous words (see Section 4.4.2). Frith and Snowling's ASD sample consisted of children aged 9 to 17, although their reading age only ranged from 8:1 to 10:2 years (IQ 54-103, 50% with average IQ, 50% with below average IQ) indicating a heterogeneous sample; thus conclusions generalising to the overall ASD population should be made with caution.

In general, it seems that local aspects of language processing are intact in (verbal) individuals with ASD.

### 4.4.2 Local coherence: Use of context for ambiguous words in sentences

Local coherence involves use of context/coherence on a local level. "Local" in this case does not mean single items (e.g. words, grammatical forms) but entails one to three sentences that can be held in short-term memory at one time (Jolliffe & Baron-Cohen, 1999). Therefore, tasks like the homograph reading task (e.g. Frith & Snowling, 1983, Section 4.4.2.1) or ambiguous sentence task (e.g. Norbury, 2005a, Section 4.4.2.2), would fall under local coherence tasks, even if they are commonly referred to as global processing tasks.

#### 4.4.2.1 Homograph reading tasks

The homograph reading task was developed by Frith and Snowling (1983) and extended by the same authors (Snowling & Frith, 1986). Participants were asked to read sentences that included homographs (ambiguous words with one spelling but different pronunciations and meanings), e.g. 'He had a pink BOW' vs "He made a deep BOW". Such homographs have a *dominant* (more frequent) and *subordinate* (less frequent) meaning. The context helping to disambiguate the homograph can be given in the sentence *before* the homograph as in the example sentences (as in Frith & Snowling, 1983; Snowling & Frith, 1986), or afterwards (as in Snowling & Frith, 1986). Homographs can thus be processed separately, which would usually lead to the more frequent pronunciation/meaning being selected (local); or in context, which would lead to the more context-appropriate meaning to be chosen (global; however, note that this should rather be called local coherence based on the above definition).

Frith and Snowling (1983) had demonstrated normal single word reading in participants with ASD. However, in their homograph reading task, participants with ASD made significantly more errors (6/10 correct, whereas TD had 7/10 correct), choosing the more frequent/dominant pronunciation independently of the sentence context, and they were not aware of their reading mistakes. Frith and Snowling thus concluded that participants with ASD showed impaired semantic processing and failure to utilise contextual cues when reading. They related these results to their previous findings of individuals with ASD ignoring context in the visual EFT (Shah & Frith, 1983).

The same authors (Snowling & Frith, 1986) repeated and extended the homograph reading task a few years later with different samples: children with below average NVP scores (with and without ASD) and children with high and low verbal ability (with/without ASD). Snowling and Frith found that in the homograph reading task children with and without ASD and with a verbal mental age of 7+ could be made aware of the special status of homographs (in a pre-training session) and read them correctly, whereas those with a verbal mental age of 5-7, chose the more frequent pronunciation (despite the pre-training). A lack of context use for disambiguation would, therefore, be not an ASD specific characteristic but was associated with *low verbal mental age* (as measured by the British Picture Vocabulary Scales).

Happe (1997) performed the homograph reading task without the pre-training and found that although overall the performance of TD and ASD was similar, participants with ASD (aged 8-28) were less able to use context information (i.e. when the homograph appeared at the end of the sentence) than TD controls (aged 7-8). The ASD group also tended to not self-correct their errors, though TD did.

Jolliffe and Baron-Cohen (1999, Experiment 1) tested high-functioning adults with ASD on the homograph reading task and found similar results to Frith and Snowling (1983) and Happe (1997): participants with ASD showed reduced use of context information compared to TD controls (matched on age, sex, VP, NVP). However, whereas Happe (1997) found that even TD children struggled with the correct pronunciation if the context was after the homograph, Jolliffe and Baron-Cohen (1999) found good TD performance, irrespectively of the homograph position. This could probably be attributed to the difference in participants' ages between both studies (children vs adolescents).

Together, the four studies (Frith & Snowling, 1983; Happe, 1997; Jolliffe & Baron-Cohen, 1999; Snowling & Frith, 1986) suggest that individuals with ASD show reduced spontaneous use of context when reading sentences with homographs; however, those ASD participants with relatively high verbal abilities (in contrast to those with low verbal ability) are able to use context if previously made aware of the homographs.

The potential ability to use semantic context to disambiguate ambiguous words has also been supported by Hala, Pexman, and Glenwright (2007), who showed that children with ASD showed semantic priming effects when priming homographs with semantically related and unrelated targets, and therefore not a total deficit in the use contextual information. However, priming did only benefit the first but not the second trial of the same homograph, suggesting difficulty in inhibition of recent, now irrelevant information or a deficit in switching from a previously activated meaning to the alternative one.

In another priming study, Henderson, Clarke, and Snowling (2011) who utilised a semantic priming paradigm with ambiguous words found that highly-verbal children with and without ASD performed similarly regarding early processing of semantic information (at 250ms inter-stimulus interval, ISI, where multiple meanings are accessed). However, children with ASD were impaired in selecting correct semantic representations at later processing stages (1000ms ISI, after a specific meaning had been selected) when primed with contextual information in sentences. The authors concluded that individuals with ASD may have difficulties with top-down strategies for modulating semantic processing and inhibit contextually inappropriate meanings / monitor incoming information. It needs to be considered, though, that the ASD group also showed worse performance on a reading comprehension task compared to TD despite being matched on vocabulary, word reading and other verbal skills.

In an eye-tracking experiment, Brock and Bzishvili (2013) used the homograph reading task with TD to examine what other factors lead to varying performances in this task. They argued that the task is seen as a "*good* measure *of central coherence*" (p. 1765) and *"a cornerstone of the WCC theory" (p. 1770),* although such conclusions might have insufficient grounds. They found that firstly, eye-movement patterns changed by fixating the homograph quicker with increasing trial numbers. Therefore, the eye-to-voice span increased which in turn lead to increased accuracy. Secondly, trial order played an important role with accuracy reducing for dominant pronunciations across trials when the context was before the homograph. Accuracy increased in the other conditions (dominant with context after, subordinate meaning with context after or before), showing interference from previous trials (trials were randomised). Thus, the authors showed that performance on the homograph readings task was not (solely) dependent on central coherence, but instead also on interference from previous trials, the eye-to-voice span and whether participants were able to detect mistakes (with comprehension monitoring) and adjust their eye-to-voice span. It thus seems that the performance has much more to do with overall reading skills than weak or strong central coherence; for this reason, impaired homograph reading performance might also be more likely to be found in children (TD or ASD) than adults.

Interestingly, Caruana and Brock (2014) who tested TD participants with high levels of autistic traits on a homograph task in an eye-tracking paradigm found no support for neither the WCC account nor a lack of comprehension monitoring in participants belonging to the broader autism phenotype.

Taken together, it seems that participants with ASD can show reduced performance on a reading homograph task; however, factors like general verbal ability, the ability to inhibit/suppress irrelevant information, and the design of the task itself do play a role.

The homograph task has been used in the pilot studies of this dissertation but was later on excluded from the research design (see Appendix D.3 for more details).

#### 4.4.2.2 Ambiguous Sentences Tasks

The original homograph task has methodological limitations, e.g. a very low trial number (only five different homographs per condition, 20 trials in total) and, as discussed, relies on reading skills of the participants.

A different kind of homograph task was developed by Norbury (2005a) which has also been used in an adapted version in this dissertation (AMBSENT task). 176 Sentences containing 22 different homographs were auditorily presented to the participants (which eliminated influences of reading skill), followed by a picture (ISI 1000ms). Participants had to decide whether the object in the picture (e.g. BANK) was mentioned in the sentence or not. The picture could represent either the dominant (money BANK) or the subordinate meaning of the ambiguous word (river BANK). Sentences could be neutral/unbiased (He ran to the BANK), biased towards (or priming) a particular meaning of the ambiguous word (context appropriate or inappropriate priming, e.g. *He stole from the BANK*), or start like a biased sentence but end without an ambiguous word (control sentences, e.g. *He stole from the*

*SHOP*, see also Table 6.1 on page 100). Norbury (2005a) had examined children (9-17 years) with/without ASD and with/without language impairment (LI), leading to 4 sample groups: ASD + LI, ASD + non-LI, non-ASD + LI, non-ASD + non-LI. She found that the groups showing less use of context information were not the ASD groups per se, but the LI groups (independent of ASD diagnosis). Norbury concluded similarly to Snowling and Frith (1986) that it was not the ASD status of individuals that lead to poor contextual processing but reduced language abilities.

Henderson et al. (2011, described above) had used an adapted version of Norbury's task with fewer conditions and concluded that participants with ASD had difficulties with modulating semantic processing and inhibiting contextually inappropriate meanings. However, despite matching on vocabulary, word reading, verbal working memory, non-word repetition and decoding, the ASD group showed reduced performance on a reading comprehension measure. Thus, it cannot be excluded that the worse performance on the task was due to impaired general comprehension in ASD and not because of being on the autism spectrum.

Similarly to Norbury (2005a), an eye-tracking study by Brock, Norbury, Einav, and Nation (2008) also failed to find reduced use of sentence context (i.e. fixation time on targets, that were anticipated following a constraining verb) in adolescents with ASD. Instead, they also reported that reduced sensitivity to context was dependent on language ability.

However, Bavin et al. (2014) points out in their eye-tracking study with two different HFA (IQ > 70) groups (one with more severe ADOS scores (ASD-S) and one with moderate scores (ASD-M); that language ability did not influence performance in their samples of 5 to 7-year-olds; instead, symptom severity (as assessed with the SCQ, Rutter et al., 2003) did.

Hahn, Snedeker, and Rabagliati (2015) used young children aged 6 to 9 with and without ASD and with strong verbal skills in an ambiguity eye-tracking task and found that children with ASD were as fast in disambiguating ambiguity with context as TD children (they focused on the target picture within 500ms of hearing the word). Surprisingly, they found that ASD participants with higher ADOS scores showed even more sensitivity to context than those with lower scores (which is in contrast to e.g. Bavin et al., 2014).

Jolliffe and Baron-Cohen (1999, Experiment 3) created a different ambiguous sentence test: It consisted of auditorily presented pairs of sentences from which the second one was ambiguous (common vs rare interpretation) but could be disambiguated by the first sentence that had biasing context (e.g. *John went to his art class. He drew a gun*.). TD and ASD participants (matched on age, sex, VP, NVP) were asked to choose answers that fit the meaning of the sentences (*What did John do? A) Pull out a gun, B) draw a picture of a gun, C) shoot from a gun*). Jolliffe and Baron-Cohen reported that their ASD participants performed normally on the common condition but showed reduced performance on the rare condition (especially the autism participants, but not AS). The authors interpret it as further support for reduced contextual processing in ASD; however, it is also possible that ASD experienced higher interference from the common interpretation due to lower inhibitory control which impaired performance, see also Section 4.4.6). Conversely, Vulchanova, Talcott, Vulchanov, Stankova, et al. (2012) used this test in their AS case-study and found that the participant I.A. performed not worse but indeed *better* than the control group. Vulchanova et al. questioned therefore whether resolving ambiguity in single sentences should be classed as global and not indeed as *local,* and therefore, potentially, even represent a strength in AS participants (enhanced local processing / local coherence), which would also be consistent with Hahn et al. (2015).

A different type of ambiguous sentences are syntactically ambiguous sentences (e.g. *She approached the butterfly on the log*). Riches, Loucas, Baird, Charman, and Simonoff (2016) used them to compare language processing in adolescents with/without ASD and with/without language impairment (LI). Riches et al. hypothesised that participants with ASD would show smaller effects of plausibility, i.e. similar RTs to pictures of plausible and implausible interpretations, due to neglecting global aspects (e.g. background assumptions based on world knowledge, e.g. that butterflies often sit on logs) and focussing on local information (two possible syntactic structures). However, there were no significant interactions between ASD status or LI status and plausibility on the RT and accuracy data. In general, the ASD and LI groups performed similar to TD (responding faster to plausible than implausible interpretations), resulting in no supportive evidence for neither the WCC theory nor the account that ASD participants show WCC due to an overall language impairment.

See Table 4.1 for an overview of the presented studies.

#### 4.4.2.3 Local Coherence Inferences Tasks

Another task to test local coherence, i.e. *"the ability to make contextually meaningful connections between linguistic information in short-term or working memory"* (Jolliffe & Baron-Cohen, 1999, p. 149) by means of bridging inferences was developed by Jolliffe and Baron-Cohen (1999, Experiment 2). Participants were given a sentence that described a situation *("George left his bath water running")* and another one that described an outcome ("*George cleared up the mess in the bathroom*"). Participants then chose from three sentences, which one was most likely missing between situation and outcome, and made the sentences coherent (e.g. the bath overflowed). Jolliffe and Baron-Cohen found that adults with a diagnosis of autism were least accurate on this task, followed with AS and then TD. Participants with autism were also slowest to choose an inference, whereas AS and TD did not differ significantly (note, however, that the reading time of the cards was included in the timing which might have influenced results). The authors saw this as a confirmation of the WCC theory, as ASD participants, especially those more affected, seemed to have a deficit in integrating information (i.e. not just a processing preference as might be the case in the homograph reading task). Vulchanova, Talcott, Vulchanov, Stankova, et al. (2012) also found in their case-study using this task that accuracy was significantly reduced in their participant ($z$ = -1.59), whereas RT was slightly faster than in the control group.

### 4.4.3 Global Processing: Figurative Language Processing

Processing of figurative language like the use and interpretation of idioms and metaphors requires global processing skills, as it involves nonliteral interpretations, i.e. interpretation of material without deriving meaning straight from its separate parts but by using its context (e.g. Vulchanova, Saldaña, Chahboun, & Vulchanov, 2015; Vulchanova, Talcott, Vulchanov, & Stankova, 2012; Vulchanova, Talcott, Vulchanov, Stankova, et al., 2012). Therefore, in order to understand/use idioms, lexical

Table 4.1

*Overview of reported studies testing context use with ambiguous sentences including sample demographics and findings*

| Authors | ASD sample | TD sample | Findings | |
|---|---|---|---|---|
| Brock et al. (2008) | 24 adolescents<br>12-17 yrs, *M* = 15.0 (1.2) | 24 adolescents<br>13-16 yrs, *M* = 14.5 (1.0)<br>(matched for age, non-verbal ability, language skills) | Reduced sensitivity to context is dependent of language ability, not ASD-diagnosis | Poor language = poor context use |
| Frith and Snowling (1983) | 8 children and adolescents<br>9-17 yrs | 10 children<br>9-10 yrs<br>(matched on gender, RA) | ASD made more errors, were not aware of mistakes | ASD < TD |
| Hahn et al. (2015) | 40 children<br>6-9yrs | 40 children<br>6-9 yrs<br>(matched on gender, age, NV IQ, language score) | ASD with strong verbal skills and TD performed similar<br>ASD with higher ADOS scores showed more context sensitivity | Good language ASD = TD |
| Hala et al. (2007) | 14 children<br>*M* = 10:4 yrs (2:6) | 14 children<br>*M* = 8:6 yrs (1:8)<br>(matched on gender, VMA, reading skills) | ASD and TD showed semantic priming effects<br>In ASD priming was only effective in the first trial of the homograph<br>→ inhibition difficulty | ASD =< TD |
| Happe (1997) | 16 individuals<br>8-28 yrs (M = 17.7) | 13 children<br>7-8 yrs (M = 7.7) | Overall TD and ASD were similar, but ASD used less context<br>ASD did not self-correct as often | ASD < TD |
| Henderson et al. (2011) | 17 children and adolescents<br>7-15 yrs (M = 11.6 (2.5)) | 17 children and adolescents<br>7-16 yrs (M = 11.5 (2.9))<br>(pairwise matched on age, receptive vocabulary, word reading; Group matching on NV ability, verbal working memory, non-word repetition, non-word decoding) | ASD and TD show semantic priming effects in early processing (ISI 250ms)<br>ASD do not show semantic priming effects in later processing (ISI 1000ms)<br>→ difficulties in top-down strategies | ASD = TD and ASD < TD |
| Jolliffe & Baron-Cohen (1999) | 17 Autism adults<br>19-46 yrs, M = 30.7 (7.8)<br><br>17 AS adults<br>18-49 yrs, M = 27.8 (7.8) | 17 adults<br>18-49 yrs, M = 30.0 (9.1)<br>(matched on age, IQ) | ASD adults showed reduced use of context information | ASD < TD |
| Norbury (2005a): | 20 ASD (non-LI)<br>9-17 yrs, M = 13.1 (1.5)<br><br>28 ASD (+LI)<br>9-17 yrs, M = 13.10(2.1)<br><br>Also: 20 LI (non-ASD)<br>9-17 yrs, M = 12.6 (1.8) | 28 TD children/adolescents<br>9-17yrs, M = 12.5 (1.7)<br>(matched on age) | Non-LI ASD and TD performed similar<br>LI ASD and non-ASD performed similar, showing less use of context information<br>→ reduced language abilities | Poor language = poor context use |
| Snowling and Frith (1986) | 8 children & adolescents<br>11-19 yrs, M = 15:3 (2:1) | 8 "mildly educationally retarded" children<br>9-16 yrs (matched on RA and IQ) | ASD and non-ASD children with verbal mental age of 7+ read homographs correctly.<br>ASD and non-ASD children with VMA of 5-7 use more frequent pronunciation. | MVA < 7 = poor context use |
| Vulchanova et al 2012 | 1 AS aged 18 with language talent | control groups matched on age (n = 20 per group) | AS participant performed better than TD | AS > TD (!) |

*Note.* VMA: verbal mental age, NV: non-verbal, RA: reading age, LI: language impaired, AS: Asperger's syndrome, ISI: inter-stimulus interval. Means (SD) are given for ages.

knowledge is required for the separate words of an idiom, and at the same time, those words need to be processed as a whole and be integrated into the context (semantic information from multiple sources).

#### 4.4.3.1 Developmental delay in ASD?

Vulchanova, Talcott, Vulchanov, and Stankova (2012) demonstrated in their case study that the participant EV performed worse in an idiom interpretation task than an age-matched control group or even younger TD children by describing idioms literally rather than metaphorically. Similar findings have been reported by Gold, Faust, and Goldstein (2010) who examined processing of figurative language in individuals with AS, and Vulchanova, Talcott, Vulchanov, Stankova, et al. (2012) who tested a language talented young adult with AS. Vulchanova, Talcott, Vulchanov, Stankova, et al. (2012) thus propose that idiom knowledge develops late in ASD compared to TD.

In line with this, Chahboun, Vulchanov, Saldana, Eshuis, and Vulchanova (2016) noted that highly verbal children (10-12 years) and young adults (16-22 years) with ASD performed worse than TD peers in a figurative language task. Despite sample matching on age, NVP, and verbal comprehension, there were significant differences, challenging the view that poor language comprehension is the main factor for reduced ability to process figurative language successfully. Chahboun et al. propose that difficulties in ASD might arise due to a developmental delay in figurative language processing (young ASD adults showed similar performance to TD children). Both TD and ASD improved in their processing skills with age, although those with ASD did not reach the standard of their TD peers. According to Vulchanova, Vulchanov, and Stankova (2011) development of idiom understanding peaks at 11 years in TD. However, the authors did not propose an age for this development in ASD.

#### 4.4.3.2 General reduced language comprehension

In contrast to the above studies, however, Gernsbacher and Pripas-Kapit (2012) point out that individuals with ASD who have general difficulties in language comprehension are those who are likely to have difficulty comprehending figurative language. Gernsbacher and Pripas-Kapit base their conclusions on findings from Norbury (2004, 2005b) who found that children *with or without* ASD but with LI show difficulties in processing figurative language (similar to what Norbury, 2005a, found regarding processing of ambiguous sentences).

However, Gold and colleagues examined young adults with AS and a control group who did not differ in verbal IQ (Gold & Faust, 2010; Gold et al., 2010). They found that participants with AS showed reduced comprehension of conventional and novel metaphors compared to TD which would thus be independent of general language comprehension.

#### 4.4.3.3 Normal and increased performance in language tasks

Other researchers, e.g. Hermann et al. (2013) and Kasirer and Mashal (2014) showed intact metaphor processing in ASD adults, and Kasirer and Marshal even demonstrated more creativity in metaphor generation in ASD compared to age-matched TD. Kasirer and Marshal further found that vocabulary and picture naming predicted comprehension of conventional metaphors. Executive function (EF) predicted comprehension of novel ones; probably, as shifting between literal and metaphoric meanings is required for novel metaphors. Lastly, the generation of new metaphors was associated with NVP.

Overall, there seems to be little agreement amongst researchers what underlying reasons for possible differences in figurative language processing between TD and ASD are. See Vulchanova et al. (2015) for an extensive review on TD and ASD figurative language processing.

### 4.4.4 Global Coherence: in Paragraphs and Longer Texts

Another aspect of global processing is text comprehension. As Jolliffe and Baron-Cohen (1999) elaborate, the term global (in contrast to local coherence) includes processing of larger chunks of text with five or more sentences that cannot be held in short-term/working memory. Global coherence is reached by connecting local chunks into higher-order chunks so that they are linked contextually (Jolliffe & Baron-Cohen, 2000). It, therefore, includes tasks like text comprehension, global inferences and global integration.

Jolliffe and Baron-Cohen (2000) developed a global integration task (called SENTORD in this dissertation) in which participants were presented with 16 stories containing five sentences each which were printed on separate cards. The sentences within each story were mixed up and participants were asked to put them in the right order *so that the story makes sense*. Thereby, they could either use temporal cues like '*in the morning…*' and therefore *local* elements of the sentences in order to rearrange them (in the temporal condition), or they had to understand the overall story and order the sentences coherently by integrating all the information within the *global* context of the story (coherence condition). A simple chaining strategy by linking two sentences that contain similar information would often not be sufficient for the coherence condition. Jolliffe and Baron-Cohen used this task with adult participants with HFA, AS and TD adults (TD matched on age, VP, NVP, sex, handedness; mean ages of groups: 27-30 yrs) and found that the clinical groups showed reduced accuracy in the coherence condition compared to the TD group, but not in the temporal condition (as also found by Vulchanova, Talcott, Vulchanov, Stankova, et al., 2012). Further, the HFA group showed more difficulties in the task than the AS group.

In their second experiment, Jolliffe and Baron-Cohen utilised a global coherence inference task in which participants had to extract and integrate information from a given story and infer why certain actions were performed by the protagonist. Again, the clinical groups showed deficits in global processing showing reduced inferencing performance (as also found by Vulchanova, Talcott, Vulchanov, Stankova, et al., 2012) with the HFA group tending to make more errors than AS participants (but not significantly). The authors stressed that the deficits were rather not due to comprehension difficulties (as comprehension was intact in control questions) but due to a coherence deficit, supporting the WCC account.

The results of both experiments indicate that those participants in the group with early language delay (HFA) have more problems with global coherence than those without early language delay (AS, TD), despite both groups showing normal verbal IQ at the point of testing. Accordingly, Helland et al. (2012) and Helland (2014) have shown that AS have intact speech and syntax scores in the CCC, while pragmatic scales are impaired.

However, HFA vs AS diagnoses are often based on parents' reports of early language development (e.g. Noterdaeme, Wriedt, & Höhne, 2010) and their accuracy could be questioned (see e.g. Lemler, 2012, for a comparison of parents' and clinician reports).

Similar results to Jolliffe and Baron-Cohen were found by Nuske and Bavin (2011) who demonstrated that children with ASD (4 to 7-year-olds) were less likely than TD children (4 to 5-year-olds) to successfully integrate information in order to make inferences, although comprehension (getting the main idea of a narrative which was also classed as a global task) was intact, giving partial support for the WCC theory.

In their meta-analysis of 36 studies, Brown, Oram-Cardy, and Johnson (2013) examined reading comprehension of texts requiring high vs. low social knowledge in individuals with ASD and TD. Brown et al. found that, on average, ASD showed poorer comprehension (especially in social texts) than TD. However, not ASD diagnosis, but semantic knowledge and decoding skills were significant predictors for comprehension. The authors conclude that comprehension deficits are independent of ASD diagnosis and rely more on language ability.

### 4.4.5 Processing styles in Language

As apparent, a considerable amount of research has been published on processing of ambiguous sentences, figurative language and other global aspects of language focusing on the question whether or not individuals with ASD can or cannot process language globally. However, instead of looking at deficits and advantages, one could examine processing preferences, i.e. processing styles in language.

Booth (2006) developed a sentence completion task (called SENTCOMP in this dissertation) in which participants were read beginnings of sentences (e.g. "He went hunting with a knife and…") and were asked to "say something to finish the sentence". Completions could be global (e.g. "gun"), i.e. fitting into the context of the whole sentence, or local, i.e. only taking the final words into account (e.g. "fork") and were therefore meant to expose a more global or local processing style in individuals. Participants were told that there were no correct or incorrect answers. Booth and colleagues used the task on children and young adults belonging to TD, ASD, and (in Booth & Happé, 2010) ADHD groups. They found accordingly to expectations that most (but not all) participants with ASD tended towards a local processing style, while those with ADHD performed similarly to TD. Further, a local completion style was not related to weak inhibitory control (an inhibition task did not correlate with completion scores); however, in one of two ASD groups, the completion score did correlate with IQ (lower IQ – more local completions). Around 25% of participants with ASD did not provide any local completions, possibly because they recognised the "*implicit requirement for global sense*" (p. 396) and applied "*compensation strategies…to avoid local completions*" (p. 390).

As Booth and Happe elaborate (Booth & Happé, 2010; Booth, 2006), more local completions in ASD might be due to a) enhanced attention to local aspects or b) reduced ability to integrate local elements. But the reason could also be a combination of both, enhanced attention to and reduced integration of local elements. Further, as Happe and Frith (2006) suggest and was discussed regarding visual perception, there could be individuals that are good in global or in local processing, in neither, or in both processing levels (see Figure 2.3 on page 32) and individuals could vary in the extent to which they can switch between processing modes. Possibly, those with AS or HFA would be better able to switch between processing styles in language (as in vision) than more affected individuals.

### 4.4.6 Explaining local and global language processing in ASD

The above elaborations have shown that the evidence regarding local and global language processing (LGLP) is very mixed. For example, regarding tasks with ambiguous sentences, some studies reported impaired use of context (Frith & Snowling, 1983; Happe, 1997; Henderson et al., 2011; Jolliffe & Baron-Cohen, 1999; Vulchanova, Talcott, Vulchanov, Stankova, et al., 2012) in ASD, although some attributed differences between groups not to ASD but general language abilities (Brock et al., 2008; Norbury, 2005a; Snowling & Frith, 1986). Others did not find any evidence for neither ASD nor language impairment status influencing results (Riches et al., 2016). In case of reduced global processing in ASD, authors have thus referred to a general language impairment, WCC, but also reduced inhibition/EF (e.g. Henderson et al., 2011). An overview and summary of the evidence for those three accounts will be presented below (Sections 4.4.6.2 et seq.).

#### 4.4.6.1 Definition of local and global in language processing

At the beginning of Section 4.4, it was explained that in language the distinction is not only between local and global processing but that there are also local and global coherence that need to be considered (Figure 4.1 on page 61). Using sentence context to disambiguate homographs is usually seen as a global processing task. However, language processing involving only one to three sentences has been advocated to be *local coherence* (Hahn et al., 2015; Happe & Frith, 2006; Jolliffe & Baron-Cohen, 1999; Vulchanova, Talcott, Vulchanov, Stankova, et al., 2012).

Therefore, a reasonable explanation for mixed results is that the ability to disambiguate ambiguous words by use of sentence context is indeed more of a *local* skill; thus, participants with ASD would show normal or similar to normal performances on these tasks. However, possibly, this is only the case for those with good overall language abilities. For participants with poorer (less than average) language skills (with or without an ASD diagnosis), disambiguating homographs could nevertheless be too advanced; thus, they would show impairments and reduced performance on these tasks.

#### 4.4.6.2 Language ability

A large and growing body of research suggests that participants with ASD perform worse than TD in language tasks requiring global processing/use of context, not because of their ASD but because of comorbid language difficulties (Brock et al., 2008; Brown et al., 2013; Gernsbacher & Pripas-Kapit, 2012; Norbury, 2005a; Snowling & Frith, 1986). For example, Brock and Bzishvili (2013) demonstrated that performance on the homograph task relies partly on simple reading skill of the participants. Despite this, other authors (e.g. Bavin et al., 2014) concluded that language ability/comprehension did not play a role when explaining global language processing.

Tager-Flusberg (2015) examined participants with ASD with and without language impairment, those with SLI and TD individuals in a non-word repetition task. The findings supported the idea that a subgroup of ASD individuals has co-morbid SLI (and performed similarly to those with only SLI, whereas ASD without SLI performed similarly to TD). Thus, if recruitment in ASD studies does not control for co-morbid language difficulties, it is possible that the comorbidity influences the performance of the ASD group leading to incorrect conclusions about language processing in ASD.

#### 4.4.6.3 Weak Central Coherence

A number of studies presented previously matched their ASD and control participants on various language ability measures (e.g. reading age, verbal mental age, receptive vocabulary, word reading, FSIQ; Chahboun et al., 2016; Gold & Faust, 2010; Gold et al., 2010; Henderson et al., 2011; Jolliffe & Baron-Cohen, 1999) and thus based reduced global processing in the ASD sample on an autism-specific mechanism, i.e. weak central coherence. It could be argued, however, that studies often match only on structural language like speech output and syntax, and thus they might have missed that participants with ASD had deficits in other language areas, e.g. pragmatic aspects (as demonstrated for AS by Helland, 2012, and Helland et al., 2014). It is debatable, however, where 'normal' language comprehension ends and global language processing begins, and thus, what measures experimental groups should be matched on.

Vulchanova and colleagues (Vulchanova et al., 2015; Vulchanova, Talcott, Vulchanov, & Stankova, 2012; Vulchanova, Talcott, Vulchanov, Stankova, et al., 2012) are strong advocates for the WCC in language processing as an equivalent to the WCC in vision. Noens and van Berckelaer-Onnes (2005) also refer to the WCC in order to explain language and communication problems in ASD. However, Heaton, Williams, et al. (2008) proposed that the WCC account might apply only to a small subgroup of ASD individuals and only to some but not all domains in the same individual (e.g. vision but not language). Hahn et al. (2015) offers two alternative explanations for their results of intact processing of ambiguous words in ASD: Either the WCC is not domain-general and applies only to the visual and auditory domains; or it is domain-general, but might only apply to ASD individuals with reduced language skills (as WCC would make it difficult to attend to context and thus cause language difficulties). Therefore, poor use of context could, after all, be not an ASD feature per-se but associated with general language impairment which is often comorbid in ASD. Note, that as discussed processing ambiguous words could be seen as a local coherence and not global processing task.

An alternative explanation for reduced global language processing in ASD involves reduced inhibition/ suppression, thus deficits in EF, and top-down control.

#### 4.4.6.4 Inhibition Deficit

Henderson et al. (2011) pointed out that although ASD participants in their study were less likely to select contextually primed appropriate meanings, their results did not completely support neither WCC, nor their proposed alternative, the semantic deficit hypothesis (which proposes that deficits in comprehension are due to deficits in semantic representation of words; this has been supported by findings in TD/poor comprehenders). Another account, the inhibition deficit hypothesis (Hala et al., 2007) suggests that language comprehension is impaired due to a dysfunction in EF and thus, inhibition of irrelevant information. This hypothesis was only partially supported by Henderson's findings. In fact, participants with ASD were contextually primed towards dominant and subordinate meanings at earlier processing stages (ISI 250ms) showing intact inhibition; but the authors speculated that an inhibition deficit might show only when the amount and frequency of the information to process is increased.

Overall, Henderson et al. (2011) concluded that individuals with ASD might have intact bottom-up semantic processing, but impaired top-down/strategic semantic processing, and are, therefore, failing to inhibit irrelevant information, to select correct meanings, and in general to maintain a *standard of coherence* which "*determines the extent to which a reader will read for understanding, make inferences, and monitor his or her own comprehension*" (Perfetti, Landi, & Oakhill, 2005, p. 233, cited in Henderson et al., 2011).

This explanation would also fit with the reduced error awareness in ASD participants that Happe (1997) reported in the homograph reading task, and Brock and Bzishvili (2013) findings that performance on the homograph reading task depended to a big part on comprehension monitoring, and following this, an adjustment of reading technique. Further, Norbury (2005) also suggests that poor comprehenders' deficits in tasks with ambiguous sentences might be based on impaired inhibition/suppression or persistent activation of irrelevant meanings which might develop with age. Similarly, Kasirer and Mashal (2012) examined TD, LI and ASD participants and found that the performance in LI resembled the ASD group and both had deficits in the suppression of irrelevant information. Suppressing irrelevant information is also crucial for understanding figurative language (Rubio Fernández, 2007; Vulchanova et al., 2015), thus could lead to reduced performance in ASD.

#### 4.4.6.5 Other reasons for mixed results

1. *Task Demands*

Task demands might play a role in whether ASD participants show impaired contextual processing or not. For example, Henderson et al. (2011) suggested that more directive tasks, like Norbury's (2005) ambiguous sentence task might benefit from top-down strategies for meaning selection more than Henderson's naming task, and therefore show better contextual processing in ASD. Similarly, Hahn et al. (2015) point out the possibility that performance might vary depending on whether the task is a more implicit or explicit measure. As apparent from the literature review, it also depends on the definition of what a global language task is and to what extent global processing is needed in order to perform successfully (cf. Figure 4.1 on page 61).

2. *Developmental aspects*

As discussed in regards to visual processing, developmental aspects play a role also in language processing and thus, studies with participants from different age groups can lead to different results. For example, most studies reviewed previously regarding local coherence used children and/or adolescent samples and only one study used adult participants (Jolliffe & Baron-Cohen, 1999), so the age ranges varied between 5 and 49 years (see Table 4.1 on page 70). It is more than likely that local global language processing (LGLP) and use of context information change throughout development.

Hahn et al. (2015) hypothesises that successful disambiguation of ambiguous words in older children with ASD (compared to younger ones) could be an example for acquired compensation skills for a previous deficit. It is likely that age and therefore (language) development play an important role and that compensation skills may influence differences that could be found between child and adult samples. However, further research is necessary to test this assumption.

## 4.5 Summary and conclusion of Chapter 4

Local and global language processing (LGLP) has been in the focus of the research community for a few decades since Frith and Snowling's (1983) first homograph reading study. Since then, a vast amount of other LGLP tasks have been developed and applied on TD and populations with ASD, ADHD, SLI/LI or combinations of those. From the literature review it is apparent that findings are mixed and there is no consensus on whether individuals with ASD do show impaired or spared global language processing, and if they are found to be impaired in certain tasks, what the underlying mechanisms for these findings are. It has been proposed that deficits in global processing in ASD can be due to, for example, weak central coherence (WCC), general language deficits, or an inhibition deficit.

The inhibition deficit hypothesis does not contradict the other accounts that poor global processing might be due to reduced language abilities or WCC (or as Hahn et al., 2015, suggested that WCC is the cause for reduced language abilities). Instead, this might be the common ground for both, explaining the process behind deficient global processing. Happe and Frith (2006) discussed the idea that ASD's deficits in figurative language might be based in difficulties in both, central coherence and EF.

We would argue that in order to process increasingly complex language material from local elements, over local coherence, global processing to global coherence (cf. Figure 4.1 on page 61), both increasing language skills as well as central coherence are necessary. With increased severity of ASD symptoms, language has been reported to be affected (Bavin et al., 2014), but also WCC/LGP (Eussen, Van Gool, Louwerse, Verhulst, & Greaves-Lord, 2016; Van Eylen et al., 2018) and EF (see Brunsdon & Happe, 2014, for a review). In ASD participants with language difficulties, a co-morbid language impairment (LI) might well contribute to poor performance on global language tasks (but also in nonword repetition task which could be classed as local, Tager-Flusberg, 2015), supporting the notion of language abilities mediating findings in language studies with ASD. However, in highly verbal individuals with ASD (and no LI), deficits or a reduction in global processing can still be found – although they are less pronounced and more difficult to pin down, and potentially only become apparent in more taxing tasks requiring more global coherence and higher executive function (EF) involvement.

To conclude, participants with ASD often struggle in studies on global language processing; but the extent might depend on the characteristics of this particular sample; in particular, age, symptom severity, language skills, central coherence, and executive function.

# 5 Aims of Investigation and Thesis structure

## 5.1 Research aims

Research reports that many individuals with ASD have remarkable local processing skills at the expense of global processing. It has been argued that this is responsible for the exceptional abilities reported in some individuals, but also the reason for the daily struggles people with ASD face.

Early research into LGP in ASD from the 1980s concluded that people with ASD have an impairment in global processing (Frith, 1989; Frith & Snowling, 1983; Shah & Frith, 1983). In contrast, later research has shown that it is not an impairment per se, but that they are simply biased towards local processing (e.g. Happe, 1999). However, as the years continued and more studies were conducted, some reported a reduction of global processing in ASD (e.g. review by Happe & Frith, 2006), whilst others did not show a global deficit (e.g. Wang et al., 2007). Thus, the findings are inconsistent.

In ASD literature, there are three dominant theories that researchers have adapted to explain general difficulties and those in LGP in ASD. These are a) the weak central coherence theory (WCC) that states that individuals with ASD have a less pronounced tendency to process information in context (e.g. Happe & Frith, 2006); b) the theory that general language difficulties are the underlying reason for reduced global (language) processing (LI, e.g. Norbury, 2005a); c) the executive dysfunction theory (ED) which suggests that problems in ASD are based on impairments in executive functions like inhibitory control, cognitive flexibility, planning or working memory (e.g. Ozonoff & Jensen, 1999).

This theses set out to first explore the question of why there are so many different and contradicting results concerning LGP and what factors might be responsible. The literature review showed that relevant factors in visual processing could potentially be stimulus characteristics (e.g. size, density fill), task characteristics (e.g. attentional demand, presentation times), or sample characteristics (e.g. autistic traits, mood, cultural background).

Second, this research aimed to investigate the development of LGP in TD and to compare its trajectory to LGP in ASD. Of particular interest was whether LGP in ASD shows a developmental delay (i.e.

individuals with ASD attain mature global processing later in life than TD), or whether is it a qualitatively different trajectory (i.e. people with ASD develop in a different direction). It was aimed to answer this by conducting a cross-sectional study with TD and ASD individuals of different age groups and examining how LGP develops from childhood to early adulthood in those samples.

The third research aim was to address a gap in the literature. LGP has mainly been examined in the visual domain, but not as extensively in language. Previous research has demonstrated that local and global language processing (LGLP) is affected in ASD participants of different ages (e.g. Jolliffe & Baron-Cohen, 1999; Vulchanova, Talcott, Vulchanov, & Stankova, 2012). However, to the best of the author's knowledge, no cross-sectional studies with a range of LGLP tasks investigating this issue have been conducted.

The fourth research aim was to explore how stable processing styles were and whether they were task- and modality-independent. For example, whether individuals who performed better in global visual perception were also better in global language processing. It was, therefore, investigated whether performance in different LGP tasks was related within modalities as well as across modalities (language and vision). Further exploration looked at how far individual differences like autistic traits influenced processing styles in the LGP tasks.

The fifth and last aim was to determine the applicability of common theories for poorer global processing in ASD: weak central coherence theory (WCC), language impairment theory (LI), and executive dysfunction theory (ED).

The aims were addressed in this thesis in the following way:

1. *Aim: To examine local and global visual perception, validate the Global Precedence Effect (GPE) in typically developing individuals and to determine what aspects influence the GPE.*

   TD adults were asked to complete a number of visual tasks to confirm the GPE, explore the flexibility of the GPE (i.e. whether is represents a processing style/preference or necessity) and examine how it was influenced by stimulus and task characteristics (PECOG study, Chapter 7).

2. *Aim: To examine how local and global visual processing develops in typical development (TD) and in ASD.*

   A large cross-sectional TD sample with participants aged 7 onwards was assessed on five hierarchical Navon-type tasks (modified from the first study). ASD children, adolescents, and adults completed the same battery of tasks and were compared to a sub-sample of age-matched TD (VISTA study, Chapter 8).

3. *Aim: To examine how local and global language processing develops in TD and ASD.*

   The same participants as for the visual paradigm were asked to complete a battery of LGLP tasks which allowed to examine different aspects of LGLP across age groups and samples (LANTA study, Chapter 9).

4. *Aim: To Explore whether individuals show similar processing styles across LGP tasks and domains (language and vision), and whether autistic traits or language abilities influence LGP.*

   A correlation analysis was conducted with selected indicators for LGP from each task as well as measures for language ability and autistic traits (Chapter 10).

5. *Aim: To illuminate the applicability of current explanatory theories for poorer global processing in ASD: weak central coherence theory (WCC), language impairment theory (LI), and executive dysfunction theory (ED).*

   The theories were evaluated in light of the findings from the experimental chapters.

## 5.2 Thesis chapter structure

In the next chapter (Chapter 6) the general methods will be presented including the ethical consideration, participant recruitment, visual and language tasks, cognitive measures, questionnaires, and general analysis methods for this project. More detailed information about the task development can be found in the appendix. The methodological chapter is followed by three experimental chapters as outlined above. The thesis concludes with the general discussion of the results and suggestions for future research.

# 6 General Method and Methodology

## 6.1 Chapter overview

This chapter provides a detailed description of the methodology of the three studies that are presented in this dissertation. Participants in the first study (PECOG) were typically developing (TD) adults, while the next two studies (VISTA, LANTA) included cross-sectional samples with TD individuals and those with ASD from the age of 7. Measures described are a battery of visual tasks (STIMMIX, CONTI, CONTMASK, see Section 6.4), language tasks (AMBWORD, AMBSENT, SENTORD and SENTCOMP, see Section 6.5), cognitive measures (WASI, see Section 6.6), and questionnaires (AQ, see Section 6.7). For a more detailed description of the development of the tasks and pilot studies please see Appendix B.

## 6.2 Ethical considerations

All the procedures in this research adhered to established ethical principles for the conduct of research with human participants (Helsinki Declaration of Ethical Principles of Medical Research of the World Medical Association, Ethical Standards for Research with Children of the Society for Research in Child Development, Code of Conduct of the British Psychological Society). This research was part of the ITN Marie Curie Project LanPercept which received ethics approval from the European Commission.

### 6.2.1 Ethical approval (Aston University)

Local ethical approval for was granted by the Life and Health Sciences Research Ethics Committee on 25/04/2014 (Project #645: The Development of Global and Local Processing in Perception and Language) and 02/07/2015 (Project #815: Global and Local Processing in Perception and Language in Typical and Atypical Populations).

### 6.2.2 Informed consent and right to withdraw

For Pilot Studies and the experiments in the PECOG study participants were informed about the study and were given the opportunity to ask questions before giving informed consent to participate.

The studies VISTA and LANTA included members from vulnerable populations (children with and without ASD, adults with ASD). Information sheets were sent to the volunteer participants and/or their parents in advance of attending the assessment. Child-friendly information sheets and consent forms were prepared to ensure child participants would understand what they were asked to do in this research. Children and parents could decide prior to commencing the test session whether they would like to participate or withdraw.

All participants were informed that they can withdraw from participation at any time of the assessments or after completion of the experiments.

### 6.2.3 Privacy and confidentiality

Privacy and confidentiality are important issues when conducting research with human participants, especially vulnerable populations. Each participant had a unique code that was used to label the Case Report Forms (CRFs) that included paper questionnaires and other confidential anonymised data as well as for the computerised tests. Consent forms with personal details on them were stored at a separate secured location to the CRFs. This was in accordance with the Data Protection Act.

### 6.2.4 Physical and psychological harm

No significant physical hazards were associated with participating in the study. Although the measures were developed for use with children as well as adults, all participants were informed that they were not expected to complete them with 100% accuracy and that mistakes were normal and not surprising. They were, however, encouraged to do their best. Participants were regularly asked whether they would like to have a break or any refreshments and could decide to stop at any time, have a longer break, come back another day or withdraw from the study completely. In some cases, children (with ASD) preferred a parent to be present during the assessment.

The assessments took place either in the Aston Brain Centre or in case of some children with ASD at the participants' homes.

### 6.2.5 Compensation

The majority of students (TD adults) were psychology undergraduate students who were given course credits for participation. Students of other subjects, adults and children (with or without ASD) received Amazon vouchers. Everyone received a certificate with stickers as a thank you for their time.

## 6.3 Participant recruitment

### 6.3.1 Healthy adult volunteers

Seventy-four healthy adult volunteers were recruited for the main studies amongst friends and colleagues of the author, amongst Aston University staff (via Aspects – Aston University Newsletter), Psychology students (via Research Participation Scheme – Sona Systems) and students of other subjects (via email from the Research Office).

In the preparatory work and pilot studies, 118 students participated. Please see Appendix B for more details about the preparatory work that was conducted.

### 6.3.2 Typically developing children and adolescents

Forty-seven Children and adolescents for the putatively typically developing group were recruited amongst children of friends, by word of mouth, the university newsletter Aspects as well as flyers distributed at public locations and events (e.g. science fairs).

Participants were aged 7 or older and of male or female gender.

Exclusion criteria for the typical control group were:

- Lack of capacity to consent/assent
- Bad general health
- Diagnosis of ASD
- Autism-Spectrum Quotient (AQ) above the cut-off point
- Full-Scale IQ < 75
- Impaired hearing (as reported by parents)

- Impaired (non-corrected) vision
- History of photosensitivity
- Neurodevelopmental, neurological or psychological disorder (as reported by parents)

### 6.3.3 Individuals with ASD

Fifty individuals with ASD were recruited through flyers, email or websites by help of the local charities *Resources for Autism* (RfA, http://resourcesforautism.org.uk) and *Autism West Midlands* (AWM, http://www.autismwestmidlands.org.uk), the *National Autistic Society / Autism Research* (NAS, http://researchautism.net), the support group *Parents Talking Asperger's* (PTA, http://www.parents-talking-aspergers.co.uk), *Swalcliffe Park School* (SPS, www.swalcliffepark.co.uk), and *Queens Alexandra College* (QAC, www.qac.ac.uk). Some participants were recruited through word of mouth. It was not recorded where each participant was recruited but the majority came from RfA, at least six from PTA, nine from SPS and one from QAC.

From 50 participants, 32 participants had a diagnosis of Asperger's syndrome (64%), 13 had an ASD diagnosis (26%), two Autism (4%), two Atypical Autism/ASD (4%) and one High Functioning Autism (HFA, 2%). The participants will be labelled under the umbrella term 'ASD' equivalently to the DSM-5 classification.

Inclusion criteria for the ASD group were:

- Diagnosis of ASD (ASD, Autism, Asperger's Syndrome, PDD-NOS; clinical report as supporting evidence were provided by the parents or participants)
- Aged 8 and older
- Full-Scale IQ $\geq 75$
- Speaking in full sentences and understanding English
- Capacity to consent/assent
- Good general health
- Normal or corrected to normal vision
- Normal hearing as reported by parents (hypersensitivity acceptable)

- No history of photosensitivity

## 6.4 Visual processing tasks

The visual tasks used in this project all used hierarchical stimuli that were first introduced by Navon (1977). The stimuli were big geometrical forms (global level, e.g. a big diamond) made out of small geometrical forms (local level, e.g. small circles, see Figure 6.1 for examples). Participants would see a figure and had to respond as quickly and accurately as possible whether they saw diamonds or squares which could be *either on the global or local level* but *never on both* levels. Participants, therefore, had to divide their attention and concentrate on both levels in order to find the target. If participants were more accurate and faster in responding to targets on the global level, they would show a global bias (or global precedence), whereas those with faster and more accurate responses to the local level would have a local bias.

3 visual tasks were developed within this project aiming to cover the following objectives:

1) To assess how stimulus characteristics influenced potential perceptive biases (STIMMIX),
2) To assess whether the biases were mandatory or could flexibly be modified (CONTI),
3) To assess what role stimulus durations/processing time played (CONTMASK).

### 6.4.1 Stimulus mix (STIMMIX)

STIMMIX was developed to assess whether stimulus characteristics influence potential perceptive biases. An initial pilot study had found a Global Precedence Effect (GPE) in participants using the stimulus set B in Figure 6.1 on page 90. It was questioned whether, instead of a real GPE, there were specific characteristics of the stimuli set that had primed the GPE. Possibly, a filled-in stimulus with a local element in the centre and therefore in foveal vision would have elicited local precedence. In order to examine this and other influences of stimulus characteristics (i.e. size, outline/filling, form), nine different sets of stimuli were developed and used in the task STIMMIX.

#### 6.4.1.1 Stimuli

The stimulus sets were adaptations from Hayward et al.'s (2012) original set (set A in Figure 6.1). The global diameter of the larger sets was approx. 3° VA and local diameter approx. 0.5° VA measured from a screen distance of approximately 60 cm. Each set consisted of four types of stimuli (as depicted in Figure 6.1) that each appeared 20 times within one condition (80 trials in total).

The stimulus sets varied in regards to

- outline/filling (whether elements were filled in on both levels like in set C, only outlined like in set B, or partially filled in and outlined like in Hayward's original set A),
- whether they had a local element in the centre of the foveal vision (sets C, G) or not (sets A, I),
- what size they were (smaller: sets D, E; or bigger: sets A, B, C).

The sets were therefore compared based on size and fill (sets B, C, D, E), form and fill (sets B, C, F, G), number of elements and fill (F, G, H, I).

Thus, the 9 stimulus sets allowed to examine the following questions:

- Do outlined vs. filled in vs. mixed stimuli (sets ABC & FG & HI) lead to similar results and is the GPE therefore independent of filling?
- Does the GPE reduce when the stimuli have a local element in the foveal vision (sets G, I)
- Is the GPE modulated by the type of geometrical form that is used or is it robust across different types of stimuli, i.e. circle as the neutral stimulus vs. triangle as the neutral stimulus (ABCDE vs FGHI or more specifically BC vs FG)?
- Is the GPE dependent on stimulus size, i.e. smaller vs larger overall stimulus size (BC vs DE)?
- Is the GPE dependent on the size and number of local elements (density), i.e. more vs fewer elements and smaller vs larger elements with the same global size (FI vs GH).

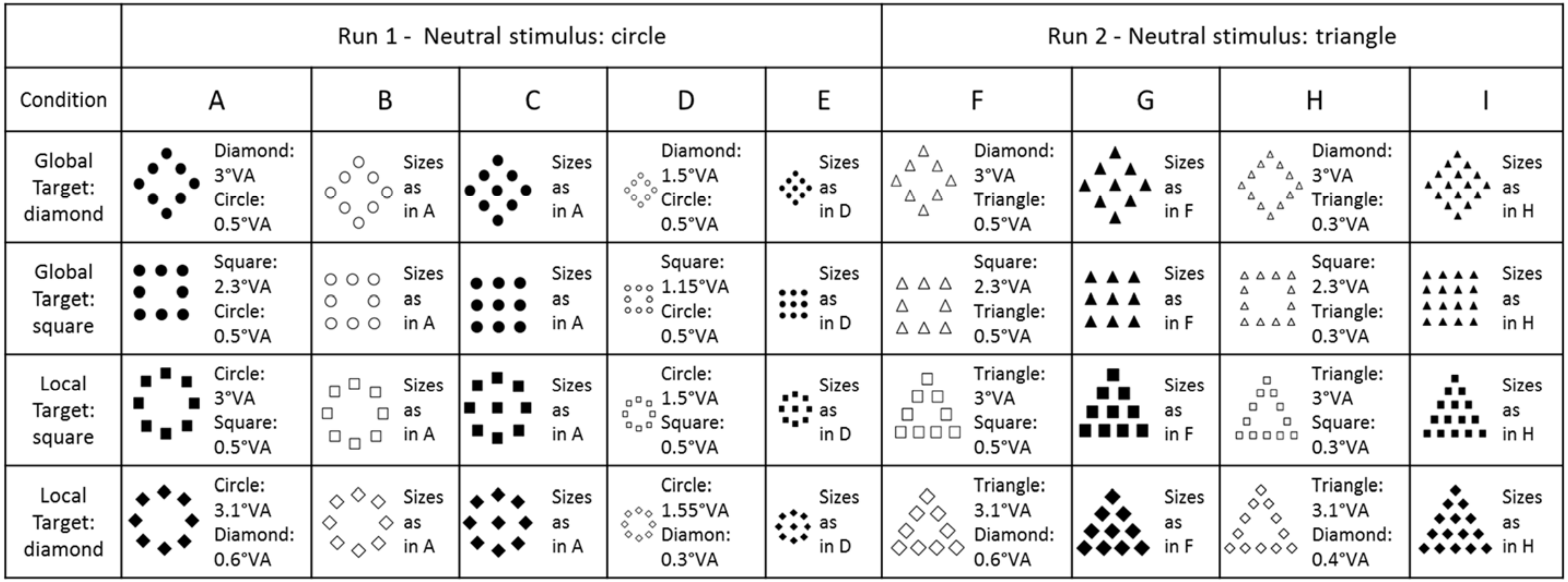



*Figure 6.1.* Stimulus sets used in STIMMIX split into two runs (A-E and F-I).
Participants started either with run 1 or run 2. The order of conditions was balanced across participants.

6.4.1.2 Procedure

All computerised experiments were set up using PsychoPy v1.82.01 Builder (http://www.psychopy.org/). The experiments were run on an HP EliteBook using the programme PsychoPy. Participants sat approx. 60cm away from the screen.

The nominal task was the same for all visual experiments: Trials started with a fixation cross (1000ms), followed by the target stimulus (150ms). Participants were asked to report by button press as quickly as possible without making mistakes whether they had seen a diamond (left arrow) or square (right arrow). From 80 trials per block, half had targets on the local and half on the global level. The tasks, therefore, required divided attention to both levels. Half of the targets were diamonds, the other half were squares. There was only one correct answer in each trial, as a target could only be on one level (diamond or square) whereas the other level had a neutral stimulus (e.g. circle). The response window was 3000ms. See Figure 6.2 for an illustration of the stimulus sequence. In the presented sequence the stimulus is a large diamond (global) made out of small circles (local). The correct response would, therefore, be a diamond (left arrow button).

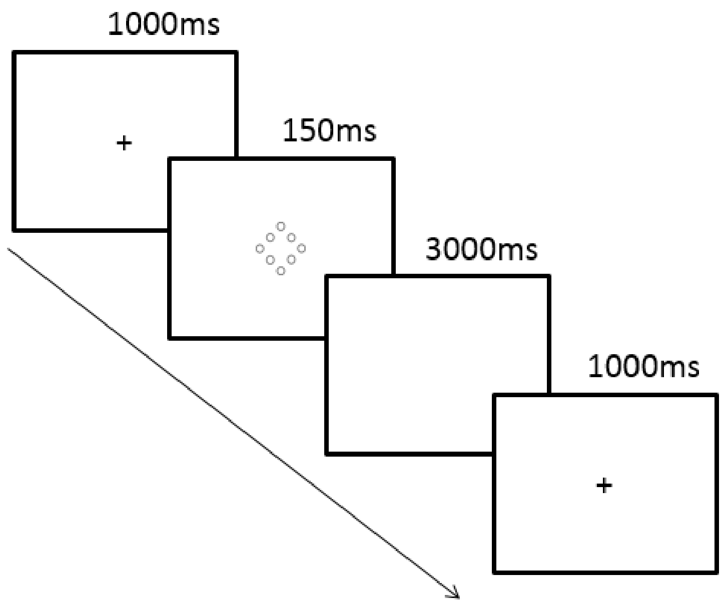



*Figure 6.2.* Schematic representation of the stimulus sequence in STIMMIX.
The stimulus is a global diamond made out of local circles. Both levels are filled in. The correct answer would be diamond.

In STIMMIX, the stimulus sets were split into two runs according to the neutral form they involved: Circles (A, B, C, D, E) and Triangles (F, G, H, I, compare Figure 6.1). Targets were always diamonds and squares. The order of runs was counterbalanced across participants as was the order of blocks within a run (using Latin Squares). Each participant responded in total to 720 trials across both runs (excl. practice trials). At the start of the experiment, participants were asked to complete 16 practice trials with feedback in order to familiarise themselves with the task. Before every new block, they completed 10 practice trials to familiarise themselves with the stimulus set. If participants made more than 2 mistakes (< 80% correct) or did not understand their mistakes, the task was explained again and more practice trials were completed until the participants and experimenter were both happy to proceed.

### 6.4.2 Contingencies (CONTI)

CONTI was developed to assess whether the GPE is mandatory or can flexibly be modified (e.g. from a global to a local bias). In the standard task, targets were equally likely to appear on the local and global level: 50% were on the local, 50% on the global level. This allowed assessing processing biases by examining the difference in RTs (and accuracy) in local and global trials. However, if the percentage of targets on either level was changed, e.g. to 20% global and 80% local targets, it would be strategically more beneficial to concentrate more on the local targets even if a participant usually had a global bias. Therefore, by manipulating the contingencies of targets on either level from 0 to 100%, the flexibility of potential processing biases could be examined.

The task was based on Hayward's et al. (2012) study in which they used hierarchical stimuli made out of diamonds, squares and circles and varied the amount of local and global targets in 6 blocks from 0% to 100%. Here, their task was adapted (CONTI) and extended (CONTMASK) using a modified stimulus set.

#### 6.4.2.1 Stimuli

Although STIMMIX did not show significant differences between its stimulus sets A and B, previous research has shown that outlined and filled-in stimuli lead to different results: List (2013) found identity-priming (i.e. priming where the target is exactly the same in two consecutive trials, e.g. local diamond → local diamond) in outlined and filled-in stimuli. However, level-priming (i.e. where the only target level in two consecutive trials is the same but not the form, e.g. local diamond followed by local square) was present only in outlined stimuli. It was therefore decided to use set B in CONTI where the stimuli were outlined on both levels.

#### 6.4.2.2 Procedure

The task was the same as in STIMMIX (see Figure 6.2 for a trial sequence).

Hayward et al. (2012) used presentation times of 3000 msec. At such long presentation times, it is possible that participants were able to shift their gaze and explore the local and global elements of the stimuli. Even without gaze shifting it could be that the long presentation times allowed for both levels to be fully processed. This might have contributed to the response performance and potentially to the finding of the GPE in both, ASD and TD participants. The stimulus presentation times in CONTI were, therefore, set to 150ms in order to prevent eye movements and to ensure that only the initial percept of the stimulus was processed, which was meant to facilitate detection of potential biases.

The total number of trials per block were 100 trials in the PECOG study. Five blocks with different contingencies, i.e. percentages of trials on the local/global level in one block were created (0, 20, 50, 80, 100%). Thus, two variables were manipulated in the task: target level (local, global) and contingency. The order of blocks was balanced across the participants. Each participant responded in total to 500 experimental trials. At the start of the procedure, participants were asked to complete 20 practice trials with feedback in order to familiarise themselves with the task. If participants made more than 4 mistakes (< 80% correct) or did not understand their mistakes, the task was explained again and more practice trials were completed until the participants and experimenter were both happy to proceed.

In the studies involving child participants, the number of trials was reduced to 80 and only 3 different contingency conditions were examined (20, 50, 80%, see also Section 6.4.4)

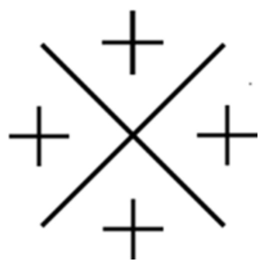
### 6.4.3 Contingencies and masking (CONTMASK)

In this experiment backward masking was introduced in order to test the hypothesis that global stimulus features are processed first and that this was the basis for the GPE. Although the stimulus presentations duration was already low in CONTI (150ms), it could not be excluded that after-images continued to be processed. Masking is a frequently implemented standard procedure in visual experiments in order to disrupt continuous processing of a stimulus. If masking does not influence global but local processing this would be another indicator for the compulsory perceptual aspect of the GPE. Although Navon's initial experiments (1977, 1981) included masking stimuli, implementing masking when examining LGP appears to be a rarity (Hübner & Kruse, 2011). Most of the cited work using hierarchical stimuli did not include masking stimuli.

Both the design and stimuli of CONTMASK were identical to CONTI, except that a 50ms masking stimulus appeared after each target stimulus.

#### 6.4.3.1 Procedure

Trials started with a fixation cross (1000ms), followed by the target stimulus (150ms) and a masking stimulus (50ms). The masking stimulus was the same size as the experimental stimuli and was made up of a large X with 4 small + between the arms of the X (see Figure 6.3a). Masks used, for example, by Navon (1977, 1981) could have potentially biased global processing due to the masking stimulus densely covering the same spatial area as the global stimulus (see Figure 6.3b). The mask in CONTMASK was chosen with the attempt to not prime perception to a particular level. The task instruction was the same as in CONTI. In the PECOG study, half of the participants started with CONTI, the other half with CONTMASK.

a) 

b) Aston University

Illustration removed for copyright restrictions

*Figure 6.3.* Masking Stimulus in a) this experiment; b) Navon (1981).

### 6.4.4 Adaptation of visual tasks for experiments with child participants

When testing younger participants and those with special needs (e.g. with ASD), experimental procedures often have to be adapted in order to make them child-friendly. Therefore, for the VISTA study which involved children, the following changes were introduced to reduce the task demand and include more breaks.

1) The total number of trials per block was reduced from 100 to 80 trials.
2) After 20 trials, the participants could take a break if needed. Each block was therefore split into 4x20 trials. Each block (including breaks) took between three minutes (fastest child) and 13 minutes (slowest child).
3) CONTI was reduced from five to three blocks (G20L80, G50L50, G80L20)
4) CONTMASK was reduced from five to only one block (labelled MASK)
5) LONG was introduced as a block in which the target stimulus was present for up to 3000 ms or until the participant responded with button press (equivalent to Hayward et al., 2012).

With these changes, the visual task was reduced to a total of 5 blocks. The participants completed those blocks alternated with language tasks or the WASI subtests in order to make the study less monotonous and more varied.

## 6.5 Language processing tasks

As reviewed in Chapter 4, LGP can also be assessed in language processing. Thereby, *local* would be understood as simple grammar, morphology or single words, *local coherence* involves use of context in short text up to three sentences, and *global* involves e.g. use of context information in more sentences/paragraphs and the ability to make inferences.

Four language tasks were implemented in this investigation (LANTA study, Chapter 9):

- Ambiguous Words (AMBWORD based on Norbury, 2005)
- Ambiguous Sentences (AMBSENT, based on Norbury, 2005)
- Sentence Ordering (SENTORD, based on Jolliffe & Baron-Cohen, 2000)

- Sentence Completion (SENTCOM, from Booth & Happe, 2010)

The first three were chosen as tasks with increasing globality (Figure 6.4).

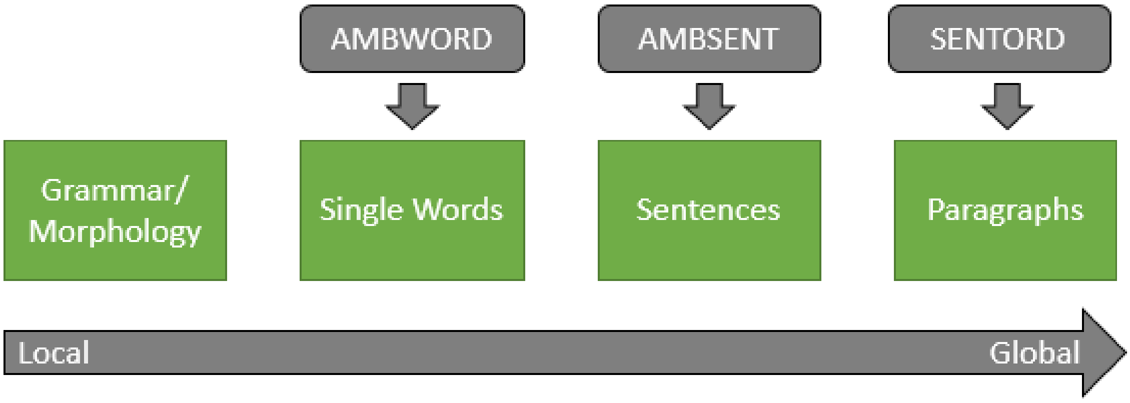



*Figure 6.4.* A continuum from local to global aspects of language processing and implemented tasks. The language tasks AMBWORD, AMBSENT and SENTORD are located on this continuum.

### 6.5.1 Procedure in the language study (Chapter 9)

Participants completed the language tasks as part of a larger assessment covering the language and perception studies (see Appendix F for the order of experiments). Most language tasks were in the first half of the assessment with alternating blocks of SENTORD, AMBWORD and AMBSENT (blocks were counterbalanced between participants). In the second assessment session (either on the same day as the first one or on different days) participants completed the task SENTCOMP (as well as the WASI and visual tasks). Towards the end of the second session, there was a 'vocabulary' task (VOCAB-CHECK) in which participants were asked to name two or more meanings of ambiguous words (e.g. jam: traffic jam, strawberry jam, music jam…). This was done in order to check whether the participants knew both meanings of the ambiguous words used in AMBWORD and AMBSENT. If a participant did not know both meanings of a specific word, this word was excluded from the analysis for that individual. Most adults and adolescents were familiar with all meanings (all adults and 82% of adolescents in TD, 95% of adults and 89% of adolescents in ASD), whereas some children were unfamiliar with both meanings in at most 3 words (TD) or 5 words (ASD). Meanings often unknown to children (or adolescents) were [vegetable] SQUASH (13% unknown in TD children, 3% in ASD children), [plant] BULB (10% in TD children, 13% in ASD children), [forehead] TEMPLE (15% in TD, 37% in ASD) and [card] DECK (5% in TD, 17% in ASD).

The first session with the majority of language tasks lasted approximately 60-120 minutes (including breaks). SENTCOMP and VOCAB-CHECK only lasted approximately 3-5 minutes each.

Next, the four tasks will be presented in more detail. The development of the language tasks AMBWORD and AMBSENT took course in three steps: 1) The stimuli were created; 2) The tasks were created and piloted; 3) The pilot data was used for an item analysis in order to select the most suitable stimuli. The detailed development, as well as pilot study results, can be found in Appendix B.

### 6.5.2 Ambiguous Words (AMBWORD)

AMBWORD was a local task in which participants had to decide whether pictures that were presented after they heard an ambiguous word could represent the meaning of that word (e.g. the word BANK followed by the picture of a river bank, the financial institution or an unrelated picture like a plane).

#### 6.5.2.1 Stimuli

Eighteen ambiguous words were each allocated to three pictures in three conditions (see Figure 6.5 on page 98): One picture with the dominant meaning, one with the subordinate meaning and one unrelated picture (from Snodgrass and Vanderwart, 1980) creating 54 different trials. A list of words and pictures can be found in Appendix C.2.

Words were read and recorded by an English native speaker with a neutral accent using the software Audacity 2.0.6 (http://sourceforge.net/projects/audacity/).

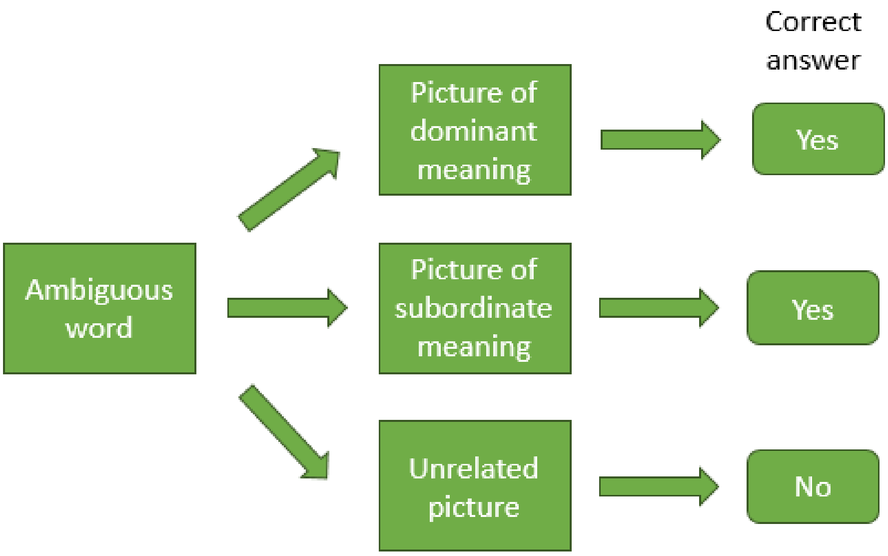
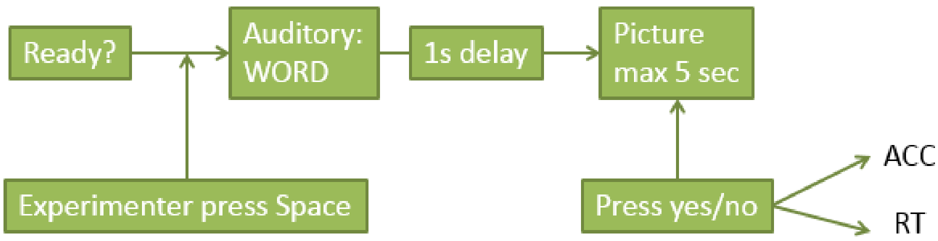



*Figure 6.5.* Possible conditions of AMBWORD.

#### 6.5.2.2 Procedure

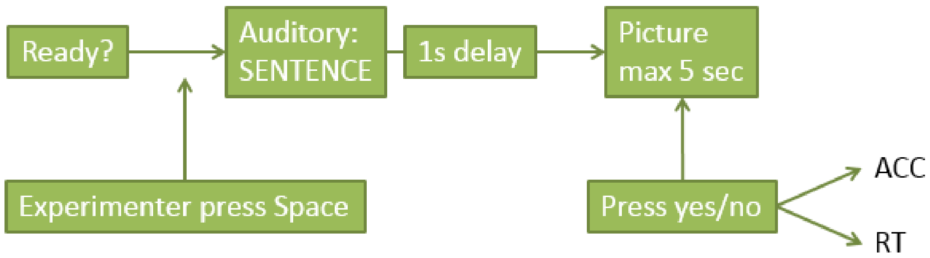
Participants heard a word (through headphones in the pilot study, through the computer speakers in the main study) followed by the presentation of the test picture after an ISI of 1000 ms. The participants had to respond with a button press (left and right arrows) whether the picture could represent the meaning of the word or not. The picture remained on the screen for five seconds or until an answer button had been pressed. Afterwards, "Ready?" appeared on the screen and the next trial could be started by pressing the spacebar. The participants were given tasks instructions in which they were made aware that '*some words could have more than one meaning*'. Each participant completed a block of 12 practice trials with feedback before proceeding to the experimental trials. If participants made an error during the practice block, the error was explained to the participant. The practice block proceeded after the participant clearly understood their error. If required, another round of practice trials was completed before commencing with the experimental trials. See Figure 6.6a for a schematic of the experimental procedure. AMBWORD consisted of one block with 54 trials lasting between 45 seconds (fastest adults in the LANTA study) and 6 minutes (slowest child in LANTA).

A)




Question: Does the object in the picture match the word?

B)




Question: Was the object in the picture mentioned in the sentence?

*Figure 6.6.* Experimental set up of the experiments A) AMBWORD and B) AMBSENT. Both tasks had two choices for answers: Yes and No. Accuracy and RT were measured.

### 6.5.3 Ambiguous Sentences (AMBSENT)

In this task which is based on Norbury (2005), participants heard sentences containing ambiguous words (but two conditions were without ambiguous words, see Table 6.1) and had to decide whether the object in the following picture was mentioned in the sentence. The picture could represent either the dominant or the subordinate meaning of the ambiguous word. Completion of this task was more successful if the context information provided in the sentence was used. AMBSENT was classed as a local coherence task based on the definition of Jolliffe and Baron-Cohen (1999).

Sentences were read and recorded by an English native speaker with a neutral accent using the software Audacity 2.0.6 (http://sourceforge.net/projects/audacity/).

#### 6.5.3.1 Stimuli

For each of the 18 ambiguous words, eight sentences were created (cf. Table 6.1). All sentences were between three and seven words long ("She likes SQUASH" and "She put the KEYBOARD on the table”). In contrast to Norbury (2005), the homograph was not always the last word in the sentence; The words JAM, KEYBOARD, FAN and SPEAKER were located within the sentence.

Each sentence type was combined with a picture representing the dominant or subordinate meaning of the ambiguous word. Half of the sentences belonged to the *contextual facilitation condition* (i.e. use of context to facilitate acceptance of the picture, types 1-4), the other half to the *contextual suppression condition* (i.e. use of context to suppress irrelevant meanings/pictures, types 5-8). A list of all stimuli can be found in Appendix C.4.

Table 6.1

*Example sentences for the word BALL*

| | Sentence type | Sentence | Picture | Correct Answer |
|---|---|---|---|---|
| | CONTEXTUAL FACILITATION condition | | | |
| 1 | Neutral (dominant) | She wanted a BALL. | Toy ball | Yes |
| 2 | Neutral (subordinate) | She wanted a BALL. | Dance ball | Yes |
| 3 | Biased (dominant) | She played with a BALL. | Toy ball | Yes |
| 4 | Biased (subordinate) | She met him at a BALL. | Dance ball | Yes |
| | CONTEXTUAL SUPPRESSION condition | | | |
| 5 | Ambiguous (dominant) | She played with a BALL. | Dance ball | No |
| 6 | Unambiguous (dominant) | She played with a DOLL. | Dance ball | No |
| 7 | Ambiguous (subordinate) | She met him at a BALL. | Toy ball | No |
| 8 | Unambiguous (subordinate) | She met him on a CONFERENCE. | Toy ball | No |

In the *facilitation condition*, sentences could be *neutral* (not biasing the dominant or subordinate meaning of the word, types 1 and 2) or *biased* (by altering the verb, the sentence primed the dominant or subordinate meaning, types 3 and 4). All sentences in the facilitation condition were followed by congruent pictures and therefore required a “yes” response. If RTs to biased sentences were faster (and accuracy higher) than to neutral ones, this implied facilitation through the sentence context (cf. Table 6.2).

In the *suppression condition*, the sentences were followed by pictures with inappropriate meanings and therefore required a negative answer. In the *ambiguous sentence* type (type 5, 7) sentences could be biased towards one meaning of the ambiguous word but be followed by the wrong picture representing the other meaning of the word (e.g. *She fished from the bank.* → *money bank picture*). Thus, in order to respond correctly, the context of the whole sentence had to be considered. In the *unambiguous sentence* types (types 6, 8) the ambiguous word was replaced by an unambiguous, unrelated word (e.g. *toy ball* → *doll*). If performance (RT/ACC) in the ambiguous and unambiguous sentence was similar, this would indicate efficient use of context. The larger the difference, the less contextual suppression (cf. Table 6.2).

Table 6.2
Possible (simplified) results in the facilitation and suppression condition with and without context use.

| | Facilitation Condition | Suppression Condition |
|---|---|---|
| Context information utilised | RT(neutral) > RT(biased) | RT(ambiguous) = RT(unambiguous) |
| | ACC(neutral) < accuracy (biased) | ACC(ambiguous) = ACC(unambiguous) |
| Context information not utilised | RT(neutral) = RT(biased) | RT(ambiguous) > RT(unambiguous) |
| | ACC(neutral) = RT(biased) | ACC(ambiguous) < ACC(unambiguous) |

*Note.* These are simplified results. It was not expected that RTs would be exactly equal between conditions.

#### 6.5.3.2 Procedure

The procedure was the same as in AMBWORD, except that, instead of a word, the participant heard a whole sentence. See Figure 6.6b on page 99 for a schematic of the procedure. Participants were asked to indicate with a button press whether or not the object in the picture was mentioned in the sentence. AMBSENT consisted of 144 trials (18 words x 8 conditions) split into two blocks. Each block lasted between 60 seconds (fastest adult in LANTA) and 8 minutes (slowest child in LANTA).

### 6.5.4 Sentence Ordering (SENTORD)

In SENTORD (Jolliffe & Baron-Cohen, 2000) participants read sentences belonging to short stories that were mixed up and had to be put in the right order, so that the stories ‘made sense’. There were two conditions: Participants had to understand and use the information provided in the whole story (in the global coherence condition) or they could rely on local temporal cues in order to solve the task (in the local temporal condition).

#### 6.5.4.1 Stimuli

From a total of 16 stories, six were identical to Jolliffe & Baron-Cohen’s (2000) stories that were supplied in their appendix (three for each condition) and 10 were created by the experimenter. See

Figure 6.7 for example stories from the temporal and coherence condition. All stories can be found in Appendix C.5).

a) **<u>A fireman's shift</u>**

The fireman left his home in the late afternoon to go on duty.
The fireman ate his dinner with the other men, whilst they were all exchanging news.
Soon after dinner the siren sounded because of a fire in town, so the men hurried to their fire engines.
All night they fought to put out the fire which had engulfed the council buildings.
In the early hours of the morning the firemen returned to the fire station.

b) **<u>A child starting school for the first time</u>**

Amy was getting ready for her first day at school.
Amy started to cry when her mother left her with the teacher.
The teacher was kind to Amy and gave her lots of new books.
Amy soon began to make friends with all the other children and started to join in their games.
When Amy was older she had to start at a new school.

*Figure 6.7*. Two stories from the SENTORD task
(original stories from Jolliffe and Baron-Cohen, 2000). a) temporal condition, b) coherence condition.

*Story characteristics*: On average, each story was made out of 68 words, 13.7 words per sentence, 4.2 characters per word and 1.4 syllables per word. Two scores were used in order to determine the readability of the stories: the Flesh Reading Ease Index[1] (FRE , Flesch, 1948, p. 229) and the Flesh-Kincaid Grade Level[2] (FKGL, Kincaid et al., 1975). The FRE was on average 73.8 (*SD* = 9.3, ranging from 59.4 - 86.9) indicating the stories were overall fairly easy (maximum FRE = 100: easy for any literate person; minimum FRE = 0: practically unreadable). The FKGL was on average 5.5 (*SD* = 1.3, ranging from 3.5-7.3) indicating that on average the stories were easily understood by children in the

[1] Flesch (1948), p. 229: $FRE = 206.835 - 1.015\left(\frac{total\ words}{total\ sentences}\right) - 84.6\left(\frac{total\ syllables}{total\ words}\right)$. Interpretation: 0-30: very difficult; 30-50 difficult; 50-60 fairly difficult; 60-70 standard; 70-80 fairly easy; 80-90 easy; 90-100 very easy.

[2] Kincaid, Fishburne, Rogers, and Chissom (1975): $FKGL = 0.39\left(\frac{total\ words}{total\ sentences}\right) + 11.8\left(\frac{total\ syllables}{total\ words}\right) - 15.59$. Interpretation: score represents U.S. grade level.

U.S. grade 5, i.e. aged 10. However, these reading ease scores need to be interpreted with caution, as they do not take into account the actual words/vocabulary in the sentences but only basic characteristics of words per sentence and syllables per words (see formulas in footnotes 1 and 2 on page 102).

#### 6.5.4.2 Procedure

The sentences were printed on small paper cards and placed in a pseudo-random order in front of the participant. The participants read the sentences aloud (at their own pace) and were then presented with the title card. The participants were asked to sort the sentences so that the story made sense. Just after the experimenter put down the title card, she said '*start*' and started the timer with a stopwatch. Accuracy and response time (RT) were measured. RTs were rounded up or down to the full second. The stories were split into two groups (with four stories per condition) which were presented counterbalanced between the participants. See Figure 6.8 for the schematic of the procedure and Figure 6.9 for the practice story (with and without temporal cues).

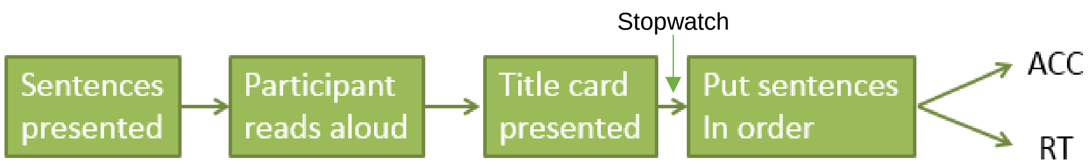



*Figure 6.8*. Experimental procedure of SENTSORT.

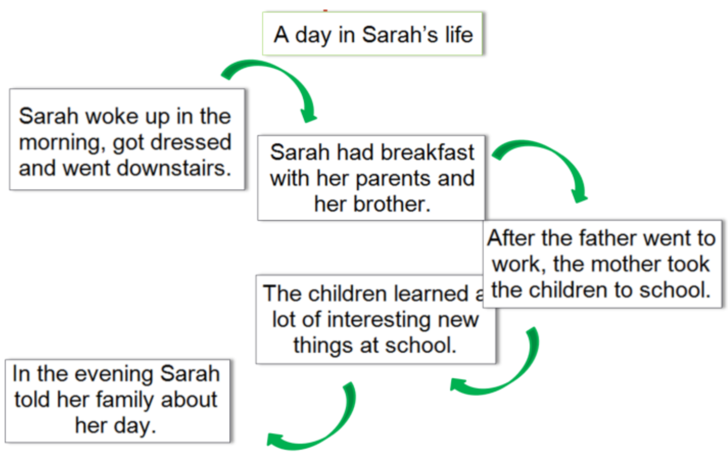



*Figure 6.9.* Practice story of the SENTORD task.
The sentences were mixed up at the start and had to be put in the correct order.

### 6.5.5 Sentence Completion Task (SENTCOMP)

SENTCOM was introduced at a later stage of the investigation. The task was a quick measure of a local bias in language. Participants were asked to complete sentence stems, whereby completions could be of local or global nature. For example, in the sentence "*He went hunting with a knife and…*" *fork* would be a local completion, whereas *gun* would be classed as a global completion.

#### 6.5.5.1 Stimuli

Sentences were taken from Booth & Happe's (2010) original task. No changes were made to the stimuli or procedure. There were 15 incomplete sentences: 10 test sentences and 4 filler sentences as well as one example sentence. The sentences can be found in Appendix C.6.

#### 6.5.5.2 Procedure

The experimenter explained the task and read the practice sentence '*He cleaned up the mess with a brush and…*'. The participants were asked to *say something to finish the sentence*. After that participants completed 14 sentences, e.g. 'In the sea there are fish and…'. Completions could be classed as *global* (e.g. dolphins, sharks etc.) or *local* (e.g. chips). Based on the answers the following measures were attained:

1) Completion Score (CS): The higher the score, the more global the processing style. Participants received 2 points for a global completion provided within the first 10 seconds; 1 point for global completions provided after 10 seconds, odd completions (that were not local) or no completion ('I don't know'); 0 points for local completions. Range 0-20.
2) Number of local responses (LC): This was a measure of a local bias with a range from 0 to 10.
3) Response Time (RT, capped at 21s equivalent to Booth, 2010)

## 6.6 Cognitive measures: WASI

The Wechsler Abbreviated Scale of Intelligence (WASI, Wechsler, 1999) contains four subtests by which a verbal performance score (VP: subtests Vocabulary and Similarities), a non-verbal performance score (NVP: subtests Matrix Reasoning and Block Design) and Full-Scale IQ (based on all four subtests:

FSIQ-4; based on 2 subtests: FSIQ-2) can be attained. Vocabulary and Matrix were used in this dissertation to gain the FSIQ-2. They were also taken for separate VP and NVP scores. The two-subtest version usually takes around 15min to complete, although there are no time limits on the tasks.

Reliability and Validity of the measures are very good (Wechsler, 1999, see Table 6.3).

### 6.6.1 Verbal Subtest: Vocabulary

The verbal performance subtest Vocabulary (providing the VP score) assesses word knowledge, verbal concept formation and fund of knowledge (WASI manual, p. 4). Participants were asked to give definitions of certain words that increase in difficulty. An example of an easy item is "What is a SHIRT?", whereas one of the most advanced ones is "Tell me what PRESUMPTIOUS means." Answers were scored with 0 to 2 points (0: wrong/no answer; 1: partially correct, 2: correct answer).

Table 6.3

*Reliability and Validity of the WASI*

| | Vocabulary | | Matrix Reasoning | | FSIQ-2 | |
|---|---|---|---|---|---|---|
| | Children | Adult | Children | Adult | Children | Adult |
| Reliability | | | | | | |
| Internal Consistency | .89 | .94 | .92 | .94 | .93 | .96 |
| Test-Retest | .85 | .90 | .77 | .79 | .85 | .88 |
| Interscorer Agreement | .98 | | (not measured but usually in the high .90s | | | |
| Validity | | | | | | |
| Correlations with WASI-III, WISC-III | .72 | .99 | --- | .66 | .81 | .87 |

### 6.6.2 Non-verbal Subtest Matrix Reasoning

The Matrix Reasoning subtest (providing the NVP score) assesses visual information processing, abstract reasoning skills/nonverbal fluid reasoning, and general intellectual ability. Participants were presented with up to 35 incomplete gridded patterns and had to choose one of 5 options to complete the pattern. Participants received one point for every item they answered correctly. Depending on their age they could receive up to 35 points.

Results of Vocabulary (VP) and Matrix Reasoning (NVP) will be presented as age-corrected T-values with $M$ = 50 and $SD$ = 10. The Full-Scale IQ with 2 subtests (subsequently labelled just FSIQ) will be reported as an IQ score with $M$ = 100 and $SD$ = 15.

## 6.7 Questionnaires

Three questionnaires were administered in this project: The Autism Spectrum Quotient (AQ) in the adult, adolescent and child version, the Social Communication Questionnaire (SCQ), and Child Communication Checklist (CCC) / Communication Checklist – Adult (CCA). The AQ will be introduced below. SCQ and CCC were implemented as proxy measures for the ASD diagnosis but were not included as variables in the analysis. They will therefore not be described in detail. More information about these tests can be found in Appendix E.

### 6.7.1 The Autism Spectrum Quotient (AQ)

The AQ was filled in for all participants and served as a screening tool for ASD symptoms in the TD and ASD populations. AQ scores were used as in the analyses of the VISTA and LANTA studies in order to examine to what extent the amount of autistic symptoms influenced performance on local and global tasks.

#### 6.7.1.1 Adult Version (AQ-Adult)

The AQ-Adult is a questionnaire developed by Baron-Cohen et al. (2001) to measure autistic traits in typical and atypical populations from the age of 17. It consists of 50 items covering 5 subscales: social skills, communication, imagination, attention to details and attention switching. The participants were asked to indicate on a scale from 1 (definitely disagree) to 4 (definitely agree) to what extent the statements applied to them (self-report). Negative answers (definitely disagree, slightly disagree) were given a score of 0, whereas positive answers (slightly agree, definitely agree) received a score of 1 (after reverse-coding some items). The scores were summed up to receive the total AQ. The maximum total score was 50. A score of 32 or more indicated a clinically significant level of autistic traits in the AQ-Adult.

Baron-Cohen et al. (2001) demonstrated good face validity (people with ASD scored higher than controls), construct validity (alpha coefficients moderate to high: Communication = .65; Social, = .77; Imagination = .65; Local Details = .63; Attention Switching = .67), and high test-retest reliability ($r$ = .7, $p$ = .002).

Although the AQ is a self-report questionnaire from the age of 17, ASD parents (if present) were asked to also answer the AQ about their children, as some of the young adults tended to show a Social-Desirability-Response-Set.

#### 6.7.1.2 Adolescent Version (AQ-Adol)

The AQ-Adol (Baron-Cohen et al., 2006) assesses autistic traits in adolescents aged 12-16 and is filled in by a parent or carer. Item content and scoring are equivalent to the AQ-Adult, but items are written in 3rd person perspective. Baron-Cohen suggested a cut-off score of 30 with scores at or above 30 indicating clinically significant levels. According to Baron-Cohen et al. (2006) internal consistency for the whole AQ-Adolescent is good at $\alpha = .79$, with the subscales ranging between .66 and .88. Test-Retest reliability is high ($r = .92$).

#### 6.7.1.3 Children's Version (AQ-Child)

The AQ-Child (Auyeung et al., 2008) is suitable for assessing autistic traits in children aged 4-11 and is completed by a parent or carer. Some AQ-adult items are rewritten to be more child-appropriate. Responses are analysed as a Likert-Scale from 0-3 points resulting in a maximum possible score of 150. The proposed cut off score is 76. According to Auyeung (2007) internal consistency for the AQ-Child was high at $\alpha = .97$, with subscales ranging between .83 and .93. Test-Retest Reliability is good ($r = .85$).

#### 6.7.1.4 Reported scores in Chapters 8 (VISTA study) and 9 (LANTA study)

In order to make the results of the child, adolescent and adult versions comparable when reported and analysed in the developmental studies of this project, the questionnaires have all been scored on a Likert-Scale from 0 to 3 (as in the AQ-Child, similar to Hoekstra, Bartels, Cath, & Boomsma, 2008, who used the original 1-4 Likert-Scale). Therefore the possible range of the AQ was 0 to 150 for all age groups.

## 6.8 General analysis methods

In general, for each participant median RTs were calculated (correct responses only), as well as accuracy (in percent). The data were compared between conditions and between groups with analyses of variance (ANOVAs) or t-tests, after being assessed regarding the assumptions of those tests. If assumptions (e.g. homogeneity of variances) were violated, the most appropriate data transformation was chosen as recommended by Field (2017, pp., e.g. in SENTORD, RTs were transformed into logarithms; for AMBWORD it was the inverse, for AMBSENT the inverse of the square-root), but original means and standard deviations are reported. In cases in which transformation did not solve the issues, non-parametric tests were selected and are reported if the results differed from the parametric equivalent. In case of a violation of Sphericity in the ANOVAs, degrees of freedom were adjusted using the Huynd-Feldt correction (if the Greenhouse-Geisser estimate of Sphericity $\varepsilon$ was greater than .75) or Greenhouse-Geisser correction (if $\varepsilon$ was less than .75). Post-hoc tests / pairwise-comparisons were performed with Bonferroni corrections. The accepted alpha level was $\alpha = .05$.

Please see the experimental chapters for more detailed descriptions of the conducted analyses.

In Chapter 7 (PECOG study), ANOVA results will be reported in the main body of the text. However, Chapters 8 (VISTA study) and 9 (LANTA study), only provide *p*-values, in order to ensure readability despite the more complex analyses. The full statistical results and descriptives can be viewed in Appendix G (VISTA) and Appendix H (LANTA).

A table of all indices, e.g. bias indicators, used in this dissertation can be found in Appendix A.

# 7 Local and global processing in typical development: perceptual and cognitive aspects (PECOG)

## 7.1 Chapter overview

This chapter presents the findings of our PECOG study into PErceptual and COGnigtive aspects of LGP, more precisely, how far stimulus and task characteristics influence the global precedence effect (GPE) and to what extent the GPE is mandatory or can be overcome in participants. The study involved three experiments that built upon each other.

## 7.2 Introduction

In the literature review in Chapter 2, experimental designs involving hierarchical figures (Navon, 1977, 1981) were introduced. Hierarchical figures are stimuli that have (at least) two percepts or levels, e.g. bigger geometrical forms like squares that are made out of smaller geometrical forms like circles, and can be used to assess local and global visual processing in participants.

The general consensus amongst the scientific community is that TD individuals show a global processing bias, or GPE that presents itself by reduced RTs to and/or increased accuracy in trials with global targets compared to local targets in hierarchical figures (Hayward et al., 2012; Krakowski et al., 2015; Navon, 1977, 1981). However, as was discussed in Sections 2.4 to 2.6, there are factors that can potentially influence LGP, for example, interindividual factors like cultural background (Oishi et al., 2014), mood (e.g. Baumann & Kuhl, 2005; Bianchi & Laurent, 2009, 2010; De Fockert & Cooper, 2014), personality traits (Yovel et al., 2005), autistic traits (e.g. Cribb et al., 2016), gender (Pletzer, 2014), and age (Kimchi, 2014; Nayar et al., 2015; Scherf et al., 2009; Scherf et al., 2008; Staudinger et al., 2011); but also experimental factors like stimulus size/visual angle (Blanca Mena, 1992; Kimchi, 1992; Lamb & Robertson, 1990; Lawson et al., 2002; Wang et al., 2007), stimulus density (Kimchi, 1992; Kimchi, 1998; LaGasse, 1993; Scherf et al., 2008), presentation duration (Paquet & Merikle, 1984; Wang et al., 2007), and stimulus fill (Hübner & Kruse, 2011; List et al., 2013). Accordingly, Hubner and Volberg (2005) argued that even small experimental changes can affect perceptual and cognitive processes in LGP tasks.

However, although this is an intensively investigated area, definite conclusions about what factors influence LGP and why there often are mixed results (especially when involving clinic populations or children) are still outstanding.

Similarly, it has been argued LGP might not necessarily be in a dichotomous relationship (e.g. Booth, 2006); and that the GPE or global processing bias is not as rigid as originally suggested, but indeed flexible, implicating that it is rather a cognitive style than a cognitive constraint (Happe & Frith, 2006). Accordingly, Hayward et al. (2012) demonstrated that the level of processing can be influenced by implicit priming (see also Section 2.7.2). Their experimental design was adapted for the present research while adjusting certain experimental flaws (more also in the introductions of Experiment 2).

Thus, by conducting a series of three experiments, a systematic examination of perceptual factors (stimulus characteristics) and cognitive factors (GPE flexibility) was achieved.

In Experiment 1 (STIMMIX), stimuli were used that varied across several perceptual dimensions, including size, number of elements, and form geometry in order to clarify whether and how such stimulus factors influence GPE (stimulus factors). In Experiment 2 (CONTI), the contingencies of local and global trials were varied (equivalent to Hayward et al., 2012) in order to examine implicit priming effects (PE) and the modifiability of the GPE (cognitive factors). In Experiment 3 (CONTMASK), additional backward masking was implemented to interrupt processing to further examine the perceptual bias and its flexibility (perceptual and cognitive factors).

## 7.3 Experiment 1: Stimulus-Mix

The development of the task in this experiment (STIMMIX) was motivated by the question whether a GPE might often be found purely because of the type of stimulus used: In many experiments, the stimuli are outlined on one or both levels so that there is no element in the foveal point of vision. One might ask whether this would be different if a local element was present in exactly that point of sharpest vision

(Navon, 2003; Ward, 1982). This was the initial question that motivated the manipulation of more stimulus characteristics in order to assess their influence on the GPE in this experiment.

Previous investigators demonstrated that the density of the hierarchical stimulus influences the GPE: stimuli that were less dense were more likely to elicit a local processing bias, whereas those that were denser produced a global processing bias (Kimchi, 1998; LaGasse, 1993; Scherf et al., 2008).

Other research showed that overall stimulus sizes (or visual angles) played a role in the extent to which participants showed a GPE (Amirkhiabani & Lovegrove, 1996; Blanca Mena, 1992; Kimchi, 1992; Kinchla & Wolfe, 1979; Lamb & Robertson, 1990; Lawson et al., 2002). Therefore, the comparison of results of studies that used differently sized stimuli is questionable. For example, the global stimuli of Iarocci et al. (2006) and Scherf et al. (2008) had a diameter of approximately 1.2cm, but Hayward et al. (2012), who claimed to have used Iarocci's stimuli, had global forms that were approx. 3.2cm in diameter. Bouvet et al. (2011) stimuli were even bigger with approx. 5cm. However, Lamb and Robertson (1990) demonstrated that it was not the absolute size but the relative size of the stimuli that influenced the GPE.

Initial studies (e.g. Navon, 1981) used hierarchical figures that were made out of letters, others used geometrical forms. In this research, geometrical forms were chosen in order to minimise potential difficulties with the stimulus set in less able participants with ASD (LANTA, Chapter 8). However, previous research not only differed in regards to the type of stimulus (letter vs form): Some of the global stimuli that have been used were geometrical forms that were filled-in with local elements (e.g. Scherf et al., 2008), whereas others had only outlined the global form with local elements (e.g. Bouvet et al., 2011; Hayward et al., 2012; Iarocci et al., 2006). Even though some of the global forms where filled in and others were not, they all used local elements that were filled in. List et al. (2013) demonstrated that different effects are to be expected when using outlined or filled-in stimuli: They showed that level-priming (facilitation of a response when attending to the same perceptive level in two subsequent trials) only occurred for outlined elements but not for filled-in ones, and they concluded that those elements are processed differently. As Hayward et al. (2012) examined level priming with filled-in local elements and outlined global elements, their results of similar priming effects on the local and global level must be interpreted with caution.

This first experiment examined the effect of stimulus factors on LGP biases by utilising the hierarchical figures and manipulating spatial details of the stimulus parameters. It thus assessed perceptual factors that influence processing biases. Following, in Experiment 2 one of those validated stimulus sets was used for a systematic examination of the flexibility of processing styles.

### 7.3.1 Research questions and predictions

In this first experiment, the following research questions were addressed and predictions made:

1) *Is the GPE dependent on the overall size of the global and local elements (stimulus sets BC vs DE in Figure 6.1 on page 90)?*

   It was expected that stimulus size will have an effect with smaller stimuli eliciting more global bias than larger ones (based on Blanca Mena, 1992; Kinchla & Wolfe, 1979; Lamb & Robertson, 1990; Lawson et al., 2002).

2) *Is the GPE dependent on the number of local elements, i.e. the density of the stimulus (FI vs GH)?*

   Number of elements was predicted to impact on the GPE: stimuli with more local elements, i.e. denser stimuli were expected to show a larger GPE than less dense stimuli (based on Kimchi, 1998; LaGasse, 1993; Scherf et al., 2008).

3) *Does the GPE reduce when the stimuli have a local element in the foveal vision (sets G, I)?*

   It was hypothesised that foveal presentation of a local stimulus might reduce the GPE (Navon, 2003; Ward, 1982).

4) *Do outlined vs. filled in stimuli (sets BC & FG & HI) lead to similar results and is the GPE therefore independent of filling type?*

   It was expected that outlined stimuli lead to increased GPE compared to filled in stimuli (based on Hübner & Kruse, 2011)

5) *Is the GPE modulated by the type of geometrical form that is used or is it robust across different types of stimuli, i.e. circle as the neutral stimulus vs. triangle as the neutral stimulus (ABCDE vs FGHI or more specifically BC vs FG)?*

   No predictions were made regarding the influence of type of geometrical form.

### 7.3.2 Method

#### 7.3.2.1 Participants

20 undergraduate psychology students from Aston University (8 males, 12 females) with a mean age of *M* = 21.40 years (*SD* = 2.91) took part in this experiment. 18 were right-handed.

#### 7.3.2.2 Stimuli and Procedure

A description of the stimuli and procedure can be found in the general methods (Section 6.4.1).

### 7.3.3 Results

#### 7.3.3.1 Accuracy

Accuracy was very high and near ceiling (94-97%). Due to the lack of variance in accuracy between conditions, further analyses concentrated on RTs only.

#### 7.3.3.2 Reaction Times

To evaluate the effect of level and stimulus type on RT, a repeated measures 2x9 ANOVA with the factors level (local, global) and stimulus set (sets A to H) was conducted. It revealed a significant main effect of level, $F\,(1,19) = 32.760$, $p < .001$, $\eta^2 = .633$, with RTs to global targets being consistently faster than to local ones. This demonstrated the GPE which was important for validating the paradigm. The factor stimulus set was not significant although the effect size was high, $F\,(8,12) = 1.905$, $p = .151$, $\eta^2 = .560$. Further, the interaction of Level x Stimulus Set reached significance, $F\,(8,12) = 4.598$, $p = .009$, $\eta^2 = .754$. Post-hoc pairwise comparisons of RT to local and global targets for each stimulus set revealed significant differences across most (A, B, C, D, E, F, H) but not all conditions (G, I, compare Figure 7.1).

For a more detailed analysis, three 2x2x2 ANOVA were conducted (see Table 7.1). Level was a significant main factor in all analyses. The ANOVA with the factors level (global, local), size (large, small) and fill (outlined, fill) using sets B, C, D and E additionally revealed a significant interaction of Level x Size. However, post-hoc analyses showed that responses to global targets were faster than to local targets in both, large and small stimulus sizes ($p$ = .002 and $p$ > .001, respectively), whereas responses to global targets ($p$ = .748) and local targets ($p$ = .274) did not vary between sizes.

Table 7.1

*Results of statistical analysis in the task STIMMIX*

| | | Dependent Variable: RT | | | Dependent Variable: BI | | |
|---|---|---|---|---|---|---|---|
| | | 2x2x2 ANOVA with level, size, and fill | | | 2x2 ANOVA with size and fill | | |
| sets B, C, D, E | Effect | *F* | *p* | $\eta^2$ | *F* | *p* | $\eta^2$ |
| | size | 0.188 | .669 | .01 | 7.218 | .015* | .275 |
| | fill | 1.772 | .199 | .085 | 0.006 | .941 | 0 |
| | level | 33.951 | <.001* | .641 | | | |
| | size * fill | 0.003 | .955 | 0 | 0.325 | .575 | .017 |
| | size * level | 5.818 | .026* | .234 | | | |
| | fill * level | 0.055 | .817 | .003 | | | |
| | size * fill * level | 0.512 | .483 | .026 | | | |
| | | 2x2x2 ANOVA with level, fill and number of elements | | | 2x2 ANOVA with fill and number | | |
| sets F, G, H, I | Effect | *F* | *p* | $\eta^2$ | *F* | *p* | $\eta^2$ |
| | fill | 4.032 | .059 | .175 | 0.742 | .4 | .038 |
| | number | 0.353 | .559 | .018 | 2.338 | .143 | .11 |
| | level | 15.002 | .001* | .441 | | | |
| | fill * number | 0.034 | .856 | .002 | 0.487 | .494 | .025 |
| | fill * level | 1.874 | .187 | .09 | | | |
| | number * level | 0.879 | .36 | .044 | | | |
| | fill * number * level | 0.601 | .448 | .031 | | | |
| | | 2x2x2 ANOVA with level, fill and form | | | 2x2 ANOVA with fill and form | | |
| sets B, C, F, G | Effect | *F* | *p* | $\eta^2$ | *F* | *p* | $\eta^2$ |
| | fill | 1.872 | .187 | .09 | 2.461 | .133 | .115 |
| | form | 3.261 | .087 | .146 | 1.271 | .274 | .063 |
| | level | 14.076 | .001* | .426 | | | |
| | fill * form | 0.159 | .695 | .008 | 2.769 | .113 | .127 |
| | fill * level | 1.305 | .268 | .064 | | | |
| | form * level | 1.63 | .217 | .079 | | | |
| | fill * form * level | 2.633 | .121 | .122 | | | |

*Note.* Hypothesis df = 1, Error df = 19 for all ANOVAs. Level: local vs global. Size: large vs small. Fill: outlined vs. filled. Number of elements: less vs more. Form: circle, triangle.

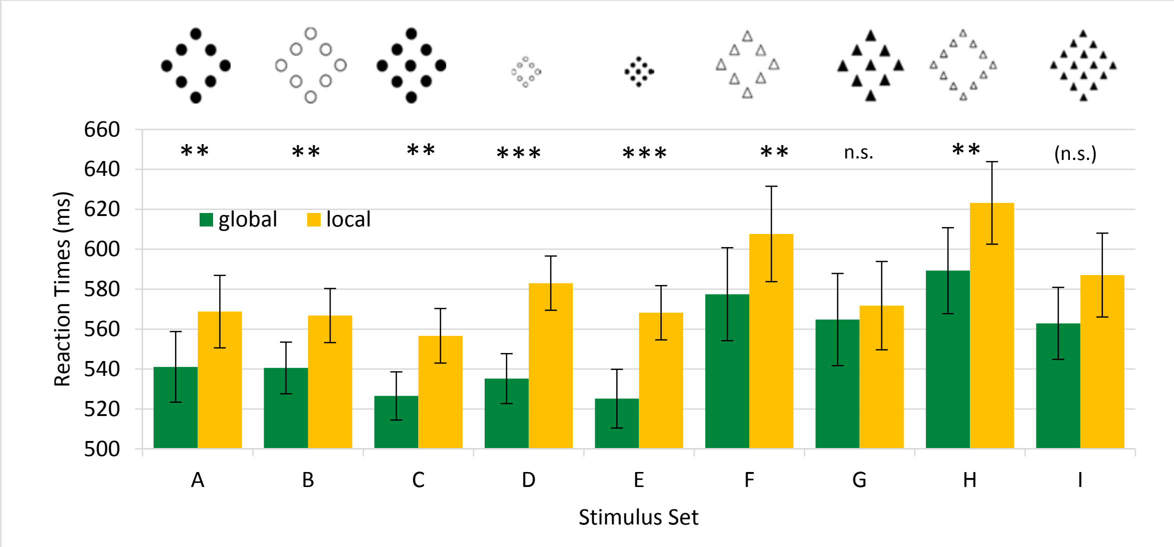



*Figure 7.1.* Mean RTs with error bars for level as a function of condition in STIMMIX. Example stimuli for the stimulus sets are presented above the chart. ***: $p < .001$, **: $p < .01$ and *: $p < .05$, n.s.: $p > .05$, (n.s.): $p = .057$.

#### 7.3.3.3 Bias Indicator.

A Bias Indicator ($BI_{RT}$) was created for the RTs by calculating a global-to-local ratio (see Formula in Appendix A) with a $BI_{RT}$ equal 1 showing equal global and local RTs (i.e. no bias), a $BI_{RT}$ less than 1 a global bias or GPE, and $BI_{RT}$ greater than 1 a local bias.

A one-way repeated measures ANOVA revealed that stimulus type influenced the BI, $F(8,12) = 5.486$, $p = .004$, $\eta 2 = .785$. Equivalently to the RT analysis, three more detailed 2x2 ANOVAs were conducted (see Table 7.1) resulting in only size being a significant factor, $F(1,19) = 7.218$, $p = .015$, $\eta 2 = .275$. The BI was lower (more global bias) for small stimuli ($M = .92$, $SD = .05$) than for bigger stimuli ($M = .95$, $SD = .06$).

The BI of every stimulus set was tested for significant difference from 1 (no bias) which revealed a significant global bias for all sets but G and I (compare Figure 7.2).

Additional comparisons were made with paired-sample t-tests between sets A and B (RTs to local and global targets, and the BIs; in order to assess whether Hayward's stimuli with mixed fill lead to different results than stimuli that were outlined on both levels), and between sets G and I (in order to assess whether having a local element in the centre of the stimulus versus no element in the exact centre influences processing). All comparisons were non-significant (A vs B: all $p > .86$, G vs I: all $p > .36$).

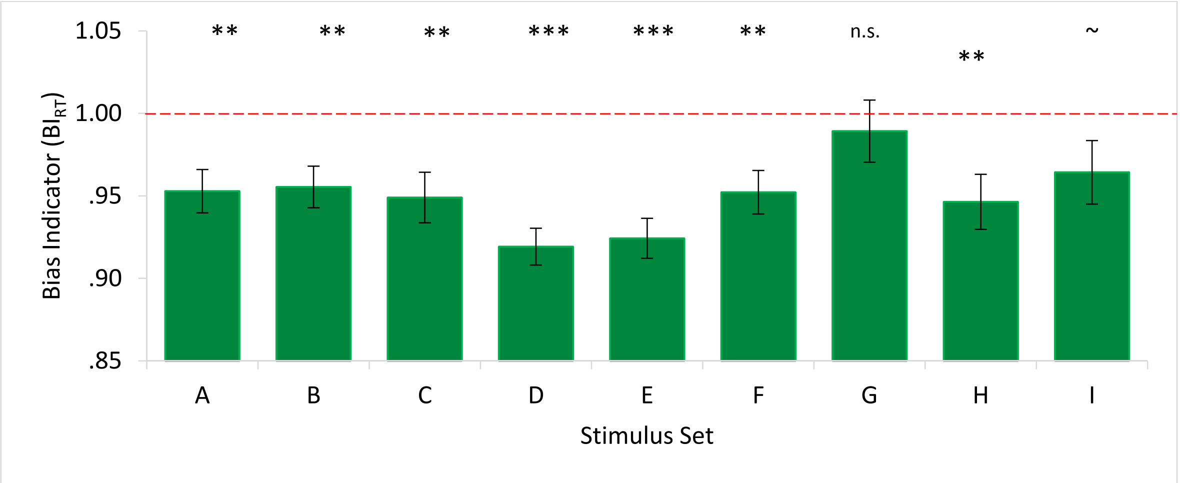



Figure 7.2. Bias Indicator BI in STIMMIX.
Means and Standard Errors are presented. The dashed line marks the point $BI_{RT} = 1$ on the y-axis where neither a local nor global bias is present. There was no significant bias in sets G and I, the other sets had a global bias (GPE). $***p < .001$, $**p < .01$, $\sim p < .1$

### 7.3.4 Discussion

We examined in a LGP task using different sets of stimuli whether the size (larger sets A, B, C, F, G; smaller sets D, E), density (denser: H, I; less dense: F, G), foveal location of local elements in filled-in stimuli (set G vs I), fill (outlined sets B, D, F, H; filled-in sets C, E, G, I), and forms (diamonds, squares and circles in sets A, B, C, D, E; diamond, squares and triangles in F, G, H, I) have an influence on how participants perceive the stimuli and to what extent processing biases can be found. Overall, a GPE was found which was important for validating the paradigm. Only stimulus size significantly influenced processing of local and global targets. The bias was more pronounced in smaller stimuli than bigger ones which was in line with previous research (e.g. Blanca Mena, 1992; Lawson et al., 2002).

It was expected that outlined stimuli would lead to a stronger GPE compared to filled-in stimuli (Hübner & Kruse, 2011). This prediction was not supported by the current data. However, a small although non-significant effect was found in sets F & H (both outlined) and G & I (both filled in): the filled in sets did not produce a significant GPE (in contrast to the outlined ones), therefore showing a trend towards the predicted outcome.

Interestingly, none of the used stimuli sets elicited a local bias in our participants, not even those that had a local element in the same position as the fixation cross (sets C, G). It could have been expected that this would lead to a local bias due to the element been in the centre of the fixation and most accurate vision (Navon, 2003; Ward, 1982). This finding is another indicator for the robustness of the GPE, which thus is mandatory on the perceptual level.

A limitation of this experiment was the stimulus selection. It would have been beneficial for the analysis to include more size variations, number of elements etc. allowing to analyse all sets in one comprehensive multifactorial ANOVA. However, a larger variety of stimulus sets would have been unfeasible and would have increased the number of assessment sessions, as that the participants were already engaged for 40-50 minutes with the current nine stimulus sets.

After validating the GPE which was mainly independent of stimulus characteristics, the next question was whether it could be modulated depending on the task, e.g. whether participants can adjust or overcome their bias if this was more beneficial for the task at hand. Stimulus set B was used in order to examine the GPE in more detail in Experiment 2.

## 7.4 Experiment 2: Contingencies

Experiment 1 demonstrated that a GPE was found in most stimulus sets and it therefore seemed to be mandatory and relatively independent of stimulus characteristics. However, previous research has suggested that a GPE might be adjustable by different processes, one of which involves priming.

Priming (level priming vs level switch) has already been introduced in Chapter 2.7, as was Haywards et al.'s (2012) study in which different contingencies of local and global trials were used in order to manipulate processing biases. Hayward et al. varied the proportion of trials in each block that was on the local or global level (from 0% to 100%) which lead to a processing advantage for the participants if they focused more on the more frequent target level in certain blocks. The authors found a global bias overall, but it was adjustable depending on the contingency. This contingency effect (CE) demonstrated the flexibility of the GPE.

Hayward et al.'s paradigm thus allows the examination of whether the implicit information about the contingencies can be used by participants in order to adjust their attention to either level which would mean the GPE was not mandatory but could be overcome. There were, however, certain limitations to Hayward et al.'s design which were addressed in the present research:

1) Hayward et al.'s stimuli were not equivalent on the local and global level, i.e. they were filled in on the local and outlined on the global level which might have influenced the accessibility/perceptibility of either level; In the previous experiment, there were some minor differences between outlined and filled-in sets (sets F, G, H, I). It was thus decided to keep both, the local and global level equivalent, i.e. outlined for the current experiment which is why stimuli set B from STIMMIX was used.

2) Hayward et al.'s stimuli were presented for a long time (3000 ms); therefore, it cannot be guaranteed that participants reacted to the first available percept. In the current experiment, stimuli were only visible for 150ms.

3) Hayward et al. (2012) conducted a switch costs analysis which differentiated only between level-switch (=not primed) and no-switch (=primed), but not between types of priming (level-priming: target is on the same level on two consecutive trials; identity-priming: target is an exact repetition of the previous trial). However, List et al. (2013) concluded from their study, that identity priming and level-priming relied on different processes. Therefore, in the current study, the distinction between types of priming was made.

In this second experiment of our study, participants were tested on the same local-global task as in SIMMIX but with only stimulus set B (outlined forms on either level). Similarly to Hayward et al. (2012), the test blocks consisted of different ratios between local and global targets which manipulated the predictability of the target level and served as implicit priming. The five blocks were: 100% global (G100), 80% global – 20% local (G80L20), 50% global and local (G50L50), 20% global – 80% local (G20L80), 100% local (L100). Thus, there were four different contingencies: 100%, 80%, 50%, 20%.

### 7.4.1 Predictions and research questions

The G50L50 block represented the 'typical' design found in other experiments in which targets are equally likely to appear on either level (as in the STIMMIX Experiment). We expected to find a global bias in the G50L50 block, represented by reduced RTs to global targets compared to local targets. If participants were able to overcome their bias and direct the attention to the local level, a local bias was expected to be found in the G20L80 block with more local trials. It was predicted that the bias would change depending on the contingencies in the block representing the contingency effect (CE).

Experiment 2 addressed the following questions:

1) *Is the GPE mandatory or can it be modulated on the basis of implicitly available information?*
2) *To what extent does the CE rely on identity, level-priming or other processes?*

   Identity-priming would suggest a simpler perceptive priming process, whereas level-priming would involve a more complex cognitive process.

### 7.4.2 Method

#### 7.4.2.1 Sample

27 participants (18 females, 9 males) with a mean age of $M = 27.25$yrs ($SD = 3.23$) took part in this experiment. None of them took part in Experiment 1. They were mostly recruited among postgraduate students of Aston University. 23 were right-handed, 4 left-handed.

#### 7.4.2.2 Stimuli and Procedure

Details about the stimuli and procedure can be found in the general methods (Section 6.4.2).

#### 7.4.2.3 Analysis

The data was analysed with two different approaches.

##### *7.4.2.3.1 Contingency Effect and Bias Indicator*

The data were first analysed with a focus on the effect of contingencies on the DV RT by conducting a 2x4 repeated measures ANOVA with the factors level (global, local) and contingency (20, 50, 80, 100%). By analysing the data based on contingencies, the processing level could be included in the analysis (e.g. RTs to local trials in the 20% contingency could be compared to those in global trials in the 20% contingency). If the data were analysed by block (e.g. G20L80), this comparison would not have been possible as it would have compared RTs to global trials in the 20% contingency to RTs to local trials in the 80% contingency. The factor contingency had four levels based on the data from five blocks, as, per definition, the 0% contingency produced no RT data.

Additionally, a 3-way ANOVA was performed examining the effect of different contingencies on the $BI_{RT}$. The $BI_{RT}$ could indicate a global bias (BI < 1), local bias (BI > 1) or no bias (BI = 1). This analysis compared the $BI_{RT}$ in each block (G80L20, G50L50, G20L80) expecting that the BI would be higher in the locally biased block (G20L80), and lower in globally biased blocks. The blocks G100 and L100 were not included as they only had one processing level and thus, no BI could be calculated.

This first approach looked at priming on the block level by means of contingencies manipulation. Higher contingencies of a certain level meant stronger priming and involved an implicit manipulation of the attended processing level (as elaborated in Section 2.7.2).

##### *7.4.2.3.2 Types of Priming on trial level*

The second (exploratory) approach focused on different types of priming on the trial level. The aim of this analysis was to explore how RTs were affected when participants experienced level-priming or identity-priming versus when they had to switch the level of attention. Level-priming occurred when two consecutive targets were on the same level of the stimuli (e.g. global) and it was the opposite of a level-switch (where consecutive targets were on different levels and therefore a switch from e.g. global to the local level was necessary). In addition to level-priming, trials could also be identity-primed where two consecutive stimuli were exactly the same (however, identity priming involves also level-priming). By means of a trial-by-trial basis, all trials (except for the first one in each block) were allocated to one of those priming conditions. Only the contingencies 50% and 80% were considered in the analysis, as the 20% condition had too few trials with level or identity-priming in order to calculate reliable effects (on average 2-3 trials per condition). On average, in the 50% contingency, from 100 trials there were 22 trials with level-switch, 30 with level-priming and 48 with identity priming. In the 80% contingency, there were 12 trials with level-switch, 38 with level-priming and 50 with identity priming. A 2x2x2 repeated measures ANOVA with the factors level (local, global), contingency (50, 80%) and priming (level, identity, none/switch) and the DV RT was performed.

Additional to the influence of priming on RTs or accuracy per se, one can also examine priming effects (PE) or switch costs (SC), which are the difference in RTs (or accuracy) between primed and nonprimed trials—two terms for the same phenomenon. Figure 7.3 visualises hypothetical example data. Figure 7.3a shows that accuracy is higher for global trials than local trials. Switch trials have lower accuracy in both levels, although the difference between switch trials and primed trials is larger when targets are on the local level. Figure 7.3b depicts these effects. The priming effect (PE) is the difference between primed vs nonprimed (or nonswitched vs switched) trials and is larger for local. Consequently, this also means that switch costs (SC) are larger, as the difference between trials with switch and without switch is larger for local than global. The terms PE and SC describe therefore the same phenomenon and will subsequently be labelled with the acronym PESC (see formulas in Appendix A). PESC were analysed in a 2x2x2 ANOVA with the factors priming (level, identity), level and contingency (50, 80%).

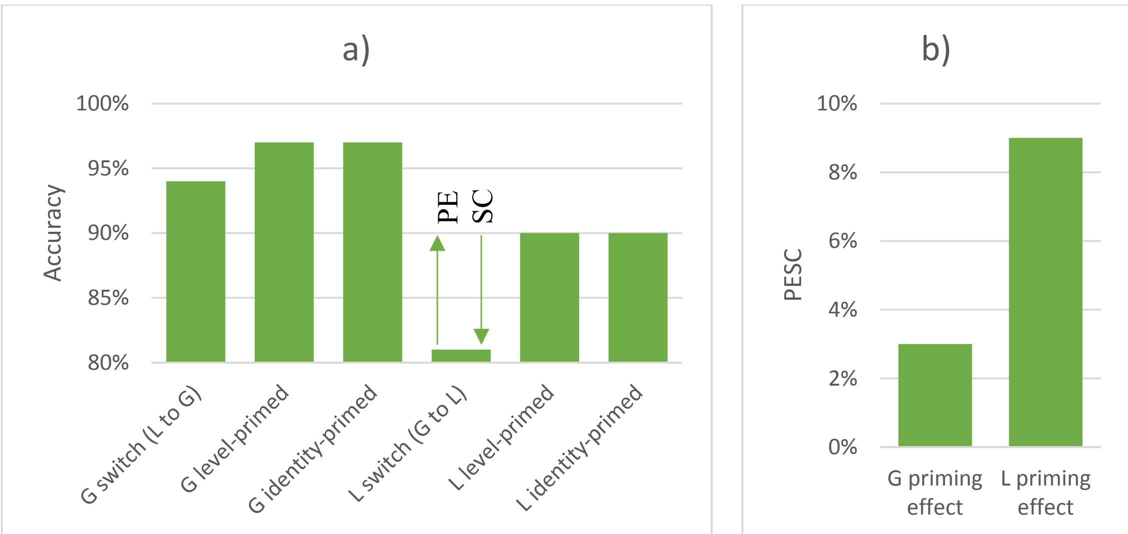



*Figure 7.3.* Hypothetical example data to visualise priming effects and switch costs (PESC).
a) showed accuracy in % per priming condition; The PE is the increase in accuracy in primed trials; the SC is the decrease in accuracy in switch trials. b) shows the equivalent PESC on the global (G) and local (L) level. Here, higher differences between switch and non-switch (or non-primed and primed) trials are found for local targets than for global. Thus, PESC are larger for local than global.

### 7.4.3 Results

#### 7.4.3.1 Accuracy

Similarly to Experiment 1, accuracy data were very high and will not be reported in this section (but see accuracy section in Experiment 3).

#### 7.4.3.2 Reaction time

##### *7.4.3.2.1 Global and Local Performance*

The 2x4 repeated measures ANOVA with the factors level and contingency revealed a significant interaction of Level x Contingency, $F(3,24) = 36.047$, $p < .001$, $\eta^2 = .818$, as well as main effects of level, $F(1,26) = 27.746$, $p < .001$, $\eta^2 = .516$ (faster reactions to global than local trials), and contingency, $F(3,24) = 35.215$, $p < .001$, $\eta^2 = .815$ (faster reactions to targets with higher contingencies).

Post-hoc tests showed participants responded faster to global targets the higher the contingency in the block (faster in G50 than G20, in G80 than G50, in G100 than G80, compare Figure 7.4), whereas responses to local targets showed a slightly different pattern: The 80% contingency L80 was not significantly faster than L50. When RTs in the same contingencies were compared between levels, responses to global targets were faster in the 50, 80 and 100% contingencies but not in the 20% contingency (compare Table 7.2).

Table 7.2

*Results from Post-hoc Tests (paired sample t-tests) comparing RTs in contingencies and levels in STIMMIX*

| Level | Contingency Pair | mean difference | *t* | *df* | *p* | *d* |
|---|---|---|---|---|---|---|
| Global | 20% vs 50% | 105.57 | 5.438 | 26 | <.001* | 1.05 |
| | 50% vs 80% | 23.31 | 2.280 | 26 | .031* | 0.44 |
| | 80% vs 100% | 70.53 | 6.561 | 26 | <.001* | 1.26 |
| Local | 20% vs 50% | 70.55 | 3.645 | 26 | .001* | 0.70 |
| | 50% vs 80% | 1.82 | .087 | 26 | .932 | 0.02 |
| | 80% vs 100% | 103.15 | 4.759 | 26 | <.001* | 0.92 |
| Contingency | Level | | | | | |
| 20% | Local vs global | 14.81 | 0.54 | 26 | .593 | 0.10 |
| 50% | Local vs global | 49.84 | 4.09 | 26 | <.001* | 0.79 |
| 80% | Local vs global | 71.33 | 2.92 | 26 | .007* | 0.56 |
| 100% | Local vs global | 38.71 | 4.18 | 26 | <.001* | 0.80 |

*Note.* d: Cohen's d (effect size)

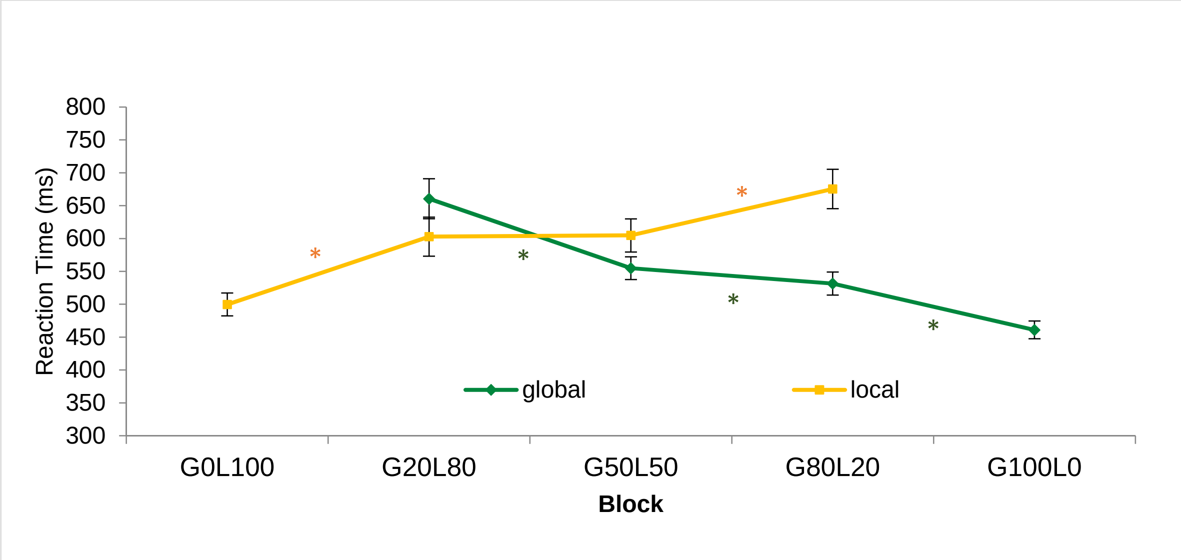



*Figure 7.4.* RTs (in ms) to global and local targets for different contingencies in CONTI.
Means and standard error bars are presented. *indicate significant differences within each processing level between the blocks.

### *7.4.3.2.2 Global Bias and its Modulation*

The $BI_{RT}$ significantly decreased the higher the contingency of global targets (main effect of contingency $p < .001$): in the G20L80 condition there was a pronounced local bias (one-sample t-test, test value = 1, $t(26) = 4.969$, $p < .001$), whereas there was a global bias in G50L50, $t(26) = -4.255$, $p < .001$, and G80L20, $t(26) = -12.731$, $p < .001$ (see Figure 7.5). The bias in the G50L50 condition ($M = .929$, $SD = .086$) was more pronounced than the one found in experiment 1 with the same stimulus set ($M = .953$, $SD = .056$), but the difference was not significant, $t(46) = 1.099$, $p = .278$, $d = .329$.

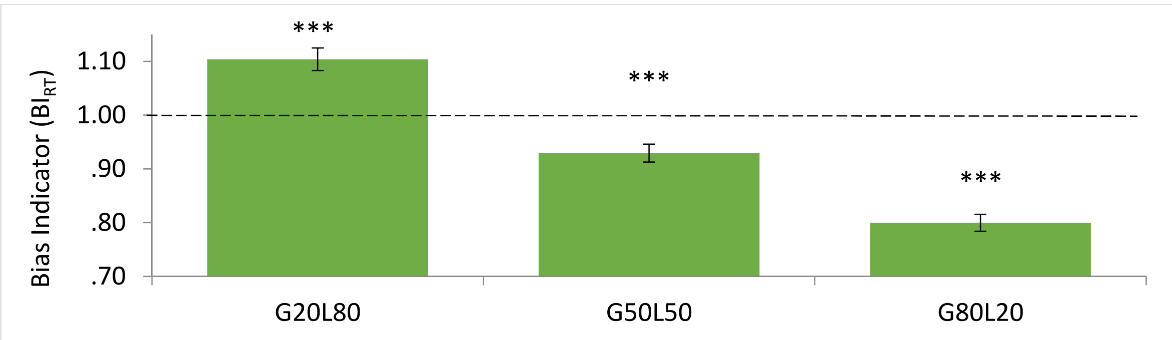



*Figure 7.5.* Bias Indicator $BI_{RT}$ in CONTI.
$BI_{RT} < 1$ indicates a global bias, $BI_{RT} > 1$ a local bias, $BI_{RT} = 1$: no bias. *** indicate significant bias ($BI \neq 1$), $p < .001$.

*7.4.3.2.3 Level and Identity-priming*

The 2x2x2 repeated measures ANOVA with the factors level (local, global), contingency (50, 80%) and priming (level, identity, none/switch) showed that priming had a highly significant effect on RTs, $F(1,25) = 29.890$, $p < .001$, $\eta^2 = .705$: RTs were fastest with identity-priming ($M = 532$ms), followed by level-priming ($M = 556$ms), and no priming ($M = 623$ms, all $p < .006$). Priming interacted significantly with contingency, $F(2.25) = 4.057$, $p = .030$, $\eta^2 = .245$: RTs were significantly higher without priming in the 80% condition ($M = 644$ms) than the 50% condition ($M = 601$ms), $t(27) = 43.220$, $p = .029$, $d = .434$, whereas there were no differences in contingencies in the level-priming or the identity-priming condition ($p > .05$, see Figure 7.6). No other interactions were significant in the ANOVA.

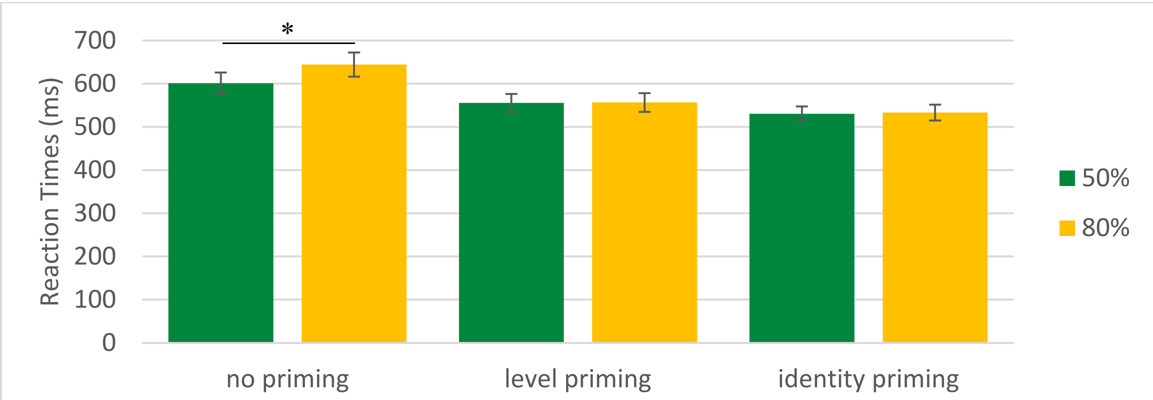



*Figure 7.6.* RTs to trials that were not primed (level switch occurred) versus those with level priming or identity priming in CONTI. RTs were comparable for the 50 and 80% condition in level- and identity-priming, but higher in 80% thaan 50% contingency when no priming (but a switch) occurred.

The analysis of PESC in the 2x2x2 ANOVA with the factors priming type (level, identity), level (local, global) and contingency (50, 80%) showed that priming type was a significant main effect, $F(1,26) = 8.909$, $p = .006$, $\eta^2 = .255$ ($PESC_{level}$: $M = 67$ms; $PESC_{identity}$: $M = 91$ms), as was contingency, $F(1,26) = 8.106$, $p = .009$, $\eta^2 = .238$. PESC were higher in the contingencies of 80% ($M = 100$ ms) than in the 50% contingency ($M = 58$ ms).

To summarise, RTs were slowest with no priming, then level, then identity-priming. Similarly, PESC were higher in identity-priming than level-priming. Although higher PESC were found in the 80%

contingency this was based on the higher RT to non-primed targets in this contingency. Level and identity-priming were not modulated by contingency or the attended processing level.

### 7.4.4 Discussion

An experiment with five blocks with different contingencies of local and global targets was implemented in order to examine the flexibility of the GPE. It was expected that the GPE could be overcome and attention could be directed to the local level if the contingency of local trials increased like in the G20L80 block.

The GPE was confirmed in the standard G50L50 block. In the G20L80 block, participants responded faster to local trials, indicating a successful adjustment of the GPE and thus the CE. This is in line with the results of Iarocci et al. (2006) and Hayward et al. (2012) who also reported a global but adjustable bias.

The data further supported the existence of the GPE across most contingencies (in contrast to blocks). Reactions were faster to global targets in the 50%, 80% and 100% condition, but not in the 20% condition. Further evidence suggested that the CE was more pronounced for the global level, as no RT differences were found in local responses between contingencies of 50% and 80%. Reductions occurred only from 20% to 50% and 80% to 100%. A possible explanation for the reduced CE on the local level could be the GPE: As participants were more focused on or tuned into processing the global level from the outset, they did not benefit as much from the increasing local contingencies.

It was further examined whether identity- and/or level-priming could be the basis for the contingency effect. Research has shown that reactions were faster with level-priming than after level-switch (e.g. Hayward et al., 2012; Hubner, 2000; Huizinga et al., 2010; Lamb & Yund, 2000; Prieto & Montoro, 2015). Higher contingencies lead to more level-primed trials which could then lead to faster RTs overall. Interestingly, we found that the PESC for level-priming effect was independent of the attended processing level, i.e. similar PESC were found when the targets were on the local or global level. Although Hubner (2000) had similar findings, other researcher found asymmetrical effects (Koivisto & Revonsuo, 2004; Shedden et al., 2003). For examples, Koivisto and Revonsuo (2004) reported priming of global primes in a globally biased block (like G80L20), but not of local primes in locally biased blocks.

List et al. (2013) examined level-priming in filled-in vs outlined geometrical hierarchical forms and found level-priming with outlined elements, but not with filled-in stimuli. Furthermore, identity-priming was found in both, outlined as well as filled-in stimuli. Level- and identity-priming seem to rely on different processes. Based on the finding that level-priming was not found in filled-in but outlined stimuli, the authors excluded the possibility that level-priming was based on a) (explicit) verbalisation-priming (participants verbalising what they saw, e.g. "global X"), or b) on participants (explicitly) sustaining their attention on the previous level, unless given a reason to shift attention. Instead, they argued that the effect was implicit and based on the *'automatic persistence of attention to perceptual scale'* (i.e. level; List, 2013 p. 7), which only applied in outlined stimuli. Similarly, Lamb, Pond, and Zahir (2000) argue that level-repetition effects are outside voluntary control and based on automatic processes like possibly persisting activation of level-specific neural mechanims. In the current experiment, significant level- and identity-priming effects were found (while using outlined stimuli). We argue that the identity-priming effects represent a *perceptual priming component* (faster recognition of the stimulus as the same neurons are re-activated), whereas level-priming represents a more *cognitive component* in the CE (faster recognitions as attention was already on that specific level).

In this experiment, we found both, significant identity priming as well as slightly weaker level-priming. If the contingency effect relied solely on implicit priming, one would expect the effect of priming to increase with increasing contingencies (Katagiri et al., 2013; Keieta et al., 2014; Wiggs & Martin, 1998). However, RTs to trials that were primed did not differ in the 50 and 80% conditions in the local level. Potentially, there was minimum RT the participants could reach and it was already reached in the 50% condition with priming and although there were relatively more trials with priming in the 80% condition, it did not reduce the mean RT further. However, because RTs to trials with level-switch were higher in the 80% than the 50% condition, the PESC was larger in the 80% condition than in the 50% condition (see Figure 7.6). Similar findings were reported by Hayward et al. (2012) as they found larger PESC in the 60% and 80% conditions compared to the 50% one (which had, in fact, no significant

PESC). It is possible (based on observations during the testing) that the high RTs in the 80% condition in switched trials are due to a startling reaction after the odd (20%) level-primed stimulus. This could have distracted the participants for the next trial where they had to switch back to the other (80%) level. Wessel and Aron (2017) described how unexpected perceptual events (post-novelty slowing, PNS) but potentially also action errors (post-error slowing, PES), lead to cognitive distraction and slower motor responses in subsequent trials. Therefore, instead of the level-switch to the 80% condition itself being responsible for the high RT, we would argue that it was the previous trial from the 20% condition that caused this effect. It is, however, impossible to confirm this with the current data.

On the whole, identity- and level-priming appear to be important modulators for the CE but cannot fully account for it, which suggests that other cognitive processes play a role in the CE. Hayward et al. (2012, p. 2391) explain the CE with *implicit learning* and state that adults "*can modify their visual processing strategy as a function of the demands on tasks with implicit […] manipulations*". Therefore, additionally to just identity- (perceptual aspect) and level-priming (cognitive aspect), there might be a more strategic (voluntary) component of the CE, in which the participants modulated their processing strategy based on implicit learning.

Hayward et al. (2012) who had filled-in local but outlined global stimuli also demonstrated priming effects but did not differentiate between identity and level-priming. It, therefore, cannot be determined whether effects in their study were based on identity or level-priming or both. List et al. (2013) only found level-priming in outlined stimuli. Even if level-priming was present in Hayward et al.'s study despite filled-in stimuli, it is possible that Hayward's long stimulus durations of 3000ms influenced the effect, as List et al. used short durations of 100ms in their task. The long stimulus duration could also account for the lack of priming effects in Haywards G50L50 condition, whereas we found a reliable effect of 58ms in this block.

In this current experiment, the stimulus duration was 150ms. This was to ensure only the first percept of the stimulus was processed and exploratory eye movements were prevented. Nevertheless, even with durations of 150ms, it could be that after-images continued to be processed. Therefore, in a third experiment, backward masking was introduced to ensure interruption of processing after 150ms. It was expected that priming would not be affected by the reduced availability of the targets (as List et al.'s presentation times were even shorter). Further, it was hypothesised that if the GPE was based on faster processing of global features (or of low spatial frequencies as suggested by e.g. Lamb & Yund, 1996; Robertson, 1996), masking would only or to a greater extent impair local processing and potentially influence the CE on the local level but not so much the global level.

## 7.5 Experiment 3: Contingencies with masking

In Experiment 3 (CONTMASK), backward masking was introduced as a more stringent way to test the hypothesis that global stimulus features are processed first and that this could be the basis for the GPE. Although the stimulus presentations duration was already low in Experiments 1 and 2, it cannot be excluded that after-images continued to be processed. Masking interrupts processing, reduces the target's visibility, and prevents processing of potential after-images (Breitmeyer & Ogmen, 2000). If masking does not influence global but local processing this would be another indicator for the compulsory perceptual aspect of the GPE as it would suggest that global aspects were already sufficiently processed by the onset of the mask whereas local ones were not. Although Navon's initial experiments (1977, 1981) included masked stimuli, implementing masking when examining LGP appears to be a rarity (Hübner & Kruse, 2011).

An example of a study implementing masking is by Hübner and Kruse (2011) who used filled-in and outlined masks and stimuli. Not only did they find different effects with different masks, they also concluded that outcomes from experiments without masking cannot be simply combined with results of experiments with masked stimuli as they can lead to different results. This makes an investigation into how masking would affect the results in the current study of particular interest, especially as to our knowledge there have not been any more studies yet that compared results for masked and unmasked stimuli. Thus, Experiment 3 was identical to Experiment 2 except for the introduction of a masking stimulus for 50ms.

### 7.5.1 Method

#### 7.5.1.1 Sample

The participants were the same as in Experiment 2.

#### 7.5.1.2 Stimuli and Procedure

The stimuli and procedure were identical to Experiment 2, except that a 50ms masking stimulus appeared after each target stimulus (See also Section 6.4.3 in the general methods chapter).

#### 7.5.1.3 Analysis

The data from Experiment 2 was used as the control data set. The same analyses were performed as in Experiment 1 but with the additional factor masking (without, with mask) in the ANOVAs to examine the effect of masking. The analyses were performed for the DVs RT and accuracy.

### 7.5.2 Results

#### 7.5.2.1 The effect of masking on RTs

The 2x2x4 ANOVA with the factors masking (with, without), level (global, local) and contingency (20, 50, 80, 100%) revealed that masking did not influence RTs: neither the main effect nor the interactions were significant (all $p > .05$).

#### 7.5.2.2 The effect of masking on accuracy

The 2x2x4 ANOVA with the factors masking (with, without), level (global, local) and contingency (20, 50, 80, 100%) revealed a significant interaction effect of Masking x Level, $F(1,26) = 5.076$, $p = .033$, $\eta^2 = .163$, but no other effects of masking ($p > .05$).

Post-hoc tests showed that masking significantly reduced accuracy for local targets ($M_{mask} = 86.0\%$, $M_{no\ mask} = 91.2\%$) but not for global ones ($M_{mask} = 93.7\%$, $M_{no\ mask} = 93.7\%$). This relationship can be seen in Figure 7.7.

#### 7.5.2.3 The effect of masking on the BI

A 2x3 ANOVA with the factors masking (with, without) and block (G20L80, G50L50, G80L20) revealed masking did not have any effects on the $BI_{RT}$ (main effect and interaction, both $p > .05$). A second 2x3 ANOVA examining the effect of those factors on the $BI_{ACC}$ (see formula in Appendix A) showed that the main effect of masking was significant, $F(1,26) = 4.574$, $p = .042$, $\eta^2 = .150$, with the $BI_{ACC}$ being lower (more global bias) with masking ($M = .92$), than without ($M = .97$).

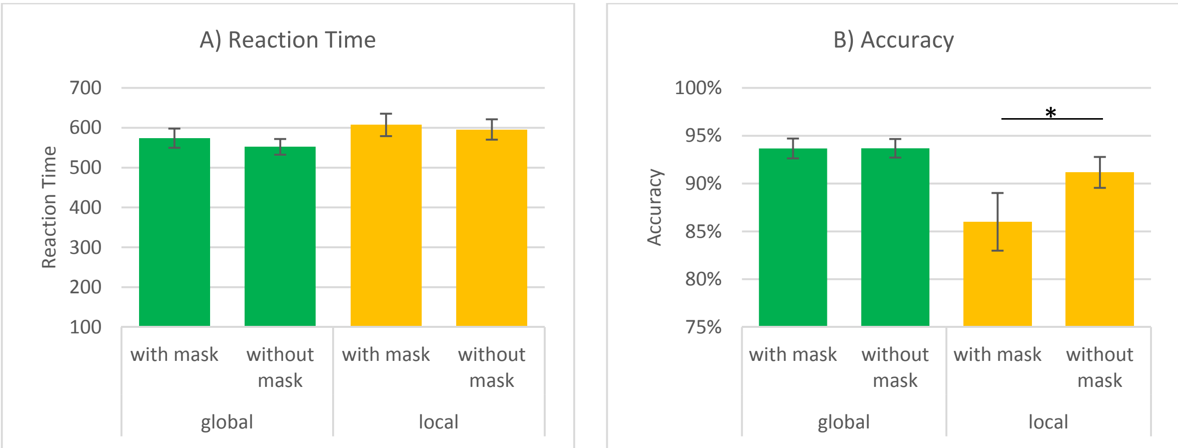



*Figure 7.7.* Reaction Times and accuracy in detecting local and global targets in CONTMASK. Displayed are RTs and accuracies for the experiment without mask (CONTI, Experiment 2) and with mask (CONTMASK, Experiment 3). The experiments were run with the same group of participants. Significant differences are marked with *.

#### 7.5.2.4 The effect of masking on level- and identity priming

The 2x2x2x3 ANOVAs with the factors masking (with, without), level (global. local), contingency (50%, 80%) and priming (none, level, identity) showed that masking had no influence on the effects of priming on RT or accuracy ($p > .05$).

### 7.5.3 Discussion

An experiment was implemented using backward masking which was introduced in order to interrupt processing of potential after-images of the stimuli. Masking has occasionally been used in experimental designs assessing LGP (Hübner & Kruse, 2011; Hubner & Volberg, 2005; Navon, 1977, 1981); however, to our knowledge, it has not yet been assessed how the implementation of a mask changed LGP compared to no mask.

No evidence was found for masking having an impact on RTs per se; however, masking had an effect on accuracy in local trials. The results of this experiment are additional evidence for a GPE on the perceptual stage in our participants. Local processing appears to be more apt to be interrupted or modified – perhaps reflecting its longer time course – than global processing which is more robust to perturbation. Masking interrupted local processing of the target stimuli and lead therefore to more errors on local trials although the RTs were as fast as without masking.

Processing of local stimuli seems to take place later, as was also demonstrated by Kimchi (1998). Kimchi examined how primes of different durations (40-690ms) influenced LGP of probe stimuli and found that a global processing style was primed by brief exposures, whereas longer exposure times primed local processing. This was, however, only the case in a many-elements task (compare Scherf et al., 2008). In the few-element task, local processing was faster than global processing. This is in contrast to our results from Experiment 1 which revealed a significant GPE regarding RTs with most of our stimuli, but not for sets with more elements like G and H.

An alternative explanation for the disruptive effect of masking on processing does not imply that it interrupted the slower local process: According to the integration hypothesis of LGP or content-level-binding theory (CLB, Hübner & Kruse, 2011; Hubner & Volberg, 2005), processing of local and global stimuli takes part in a two-step process: First, the contents of both levels are merely identified (e.g. circle and square); only at the second step the contents are actually bound to the specific levels (circle on local, square on global level). This is opposed to the "standard view" that assumes that level and identity information are processed together from the start. Hubner and Volberg (2005) provided comprehensive evidence for the CLB theory in a series of experiments with hierarchical letters, all of which involved masking. Masking, according to them, can provide sufficient time for the identification of the stimulus (content) but it disturbs or interrupts the integration or binding process of the content to the level.

Hubner and colleagues results cannot be easily applied to the current research as the experimental parameters differed: their stimuli involved letters, not geometrical forms; they used a different masking stimulus; the target level was cued before stimulus presentation, and each stimulus had two potential target levels that could be responded to (letters A, S, H, or E). In contrast, in the current experiment, only one level per trial had an appropriate response button (diamond or square), the other level was neutral and there was no button for this (circle). Hubner and Volberg (2005) who included a neutral stimulus in their third experiment (neutral letter: U) stated that for those stimuli the selected response could be based on identity information alone without involving the second step of binding the information to a level. Thus, masking should leave processing of those stimuli unaffected. This idea contrasts with the present results that showed the identification of the (local) shapes was disturbed by masking leading to reduced accuracy on the local level. Potentially the used stimulus types and masks influenced the current findings. Further future research extending the current experiments could shed light on this.

The examination of the modulating effect of masking showed that it did not influence the CE or priming. Although there seemed to be a mandatory GPE on the perceptual level, access to both, local and global information was given and could be used implicitly leading to the CE.

After closer inspection of the masking data, it appeared that only in the 80% condition there was a difference between local and global $PESC_{RT}$ with local ones being higher than global ones (Interaction level and contingency, $F(1,26) = 4.528$, $p = .043$, $\eta^2 = .148$, see Figure 7.8). It could be interpreted that successful processing of local targets was reduced by masking (as shown by accuracy data) but when the attention was consistently primed towards the local level within one block (as in the L80% condition), participants significantly improved regarding RTs. On the other hand, the larger positive effects through priming the higher the costs that arise from level-switching (see also Figure 7.3 on page 115). It appears therefore that in the 80% condition after switching to the odd global trial, a switch back from global to local level was required which was associated with high switch costs. There was a considerable disruption by occasional global targets. Either attention was not easily directed back to the predominant local level or it was the unexpected appearance of a global target that the subsequent (local) trial had slower RTs (post-novelty slowing and/or post-error slowing in Wessel & Aron, 2017). If only the unexpectedness of the event were accounting for the increased RTs after a level-switch then the effect should be the same regardless of the level from which the switch occurred. Instead, it appears that only switching from the unexpected global trial back to local was affected, not vice versa. Thus, relocating attention from global to local was more difficult, providing additional evidence for the GPE. However, this directionality is in contrast to the findings of Hubner and Volberg (2005) who demonstrated that focussing attention to a particular level after a level switch was, in fact, easier when going to the local level from the global (i.e. "zooming in" was easier than "zooming out"). The same effect was found in our developmental study (Chapter 8).

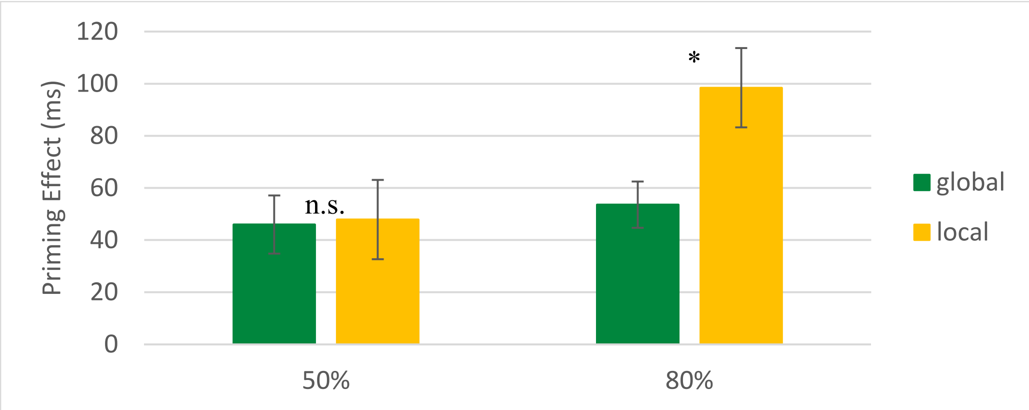



*Figure 7.8.* Priming Effects in CONTMASK for local and global trials in the 50% and 80% contingency conditions.
* indicates a significant difference between levels.

Taken together, Experiment 3 confirmed once more that the GPE was present and significant already early on the perceptual state. It could be overcome by contingency/priming effects but not easily and only at a cost. Therefore, it seems to be not a matter of choice but indeed a real bias. Masking affected the identification of local targets negatively leading to lower accuracy of the responses.

## 7.6 General discussion and conclusions

This study consisted of a series of experiments assessing LGP in TD adults. The first experiment examined the influence of stimulus characteristics on the GPE. In the second experiment, the amount of local and global trials per block was manipulated and the effect of these contingencies on the GPE was examined (cognitive factors). In the last experiment, backward masking was implemented to explore its effects on LGP (perceptual & cognitive factors).

The main findings of this study were: The GPE is mandatory on the perceptual level and is modulated only slightly by stimulus size (more global bias with smaller stimuli) but not by the other manipulated stimulus characteristics. The size effect is in line with previous research by for example by Lawson et al. (2002). Similarly to List et al. (2013) different results were found between filled-in and outlined stimuli (filled-in sets G and I did not elicit a GPE), confirming that results of studies using different stimulus types should not be too incautiously compared.

The second main finding of the present study was that the GPE could be changed to a local processing bias if contingencies of local targets increased. In our study, a CE was found for both, global and local processing; however, this effect was not as consistent in local trials. Hayward et al. (2012) had similar results despite longer stimulus durations (3000ms). It seems, therefore, that even if local elements have a high chance of being processed (in long presentation times), the GPE can still be found. The CE is likely to be based to a large extent on automatic implicit priming processes (identity priming and level priming), but also a voluntary strategic component.

The data from the masking experiment (Experiment 3) also confirmed that attention can be allocated more to the local level like in the G20L80 condition (leading to local precedence). However, this allocation did not seem to be very robust and could easily be disrupted by occasional global targets as shown by high level-switch-costs in this condition. The unexpectedness of the global target cannot fully account for this effect, as the same finding would have been expected but was not found for occasional local targets in the G80L20 condition. Together, this gives additional evidence for the mandatory perceptual GPE. As we did not find these results in Experiment 2, it seems reasonable to assume that the masking stimulus and the accompanying reduced processing time was responsible for this effect.

The third finding was that masking did not affect global processing but compromised accuracy in local trials. This suggests that local processing is more prone to interruption, potentially due to having a longer time course (compare Navon, 1981; Paquet & Merikle, 1984; Scherf et al., 2008; Wang et al., 2007). For example, Navon (1981) explains that global elements are available earlier than local ones but further elaborates that this does not imply that local processing starts only after global processing is completed (although it could be a possibility). Instead, processing on both levels might run in parallel with the global one being completed faster. The content level binding theory (CLB theory, Hübner & Kruse, 2011; Hubner & Volberg, 2005) proposes that local and global processing start together, i.e. in parallel, as the features on both levels are first only identified as such and only later allocated to a particular level. The current study showed that while masking did not influence the CE or priming effects, it affected the identification of local targets negatively. This contradicts the CLB theory as the information of the target shape (e.g. diamond) should have been unaffected by the mask. However, in our next study (VISTA, Chapter 8) this unfavourable effect of masking was not replicated in different TD adult and adolescent samples but in children.

The results reported in this chapter stem from a population of TD individuals. Hayward et al. (2012) examined TD but also individuals with ASD in their study. Although individuals with ASD are generally thought to present local precedence (cf. Chapter 3), Hayward et al. (2012) did not find significant differences between groups: both groups showed a global processing bias and flexibility regarding this bias as indicated by the CE. Potentially, this could be due to the long stimulus durations of 3000ms. It is likely that perceptual biases would more pronounced in shorter durations and therefore different results would be found if the current task was used with participants with ASD.

Additionally, the developmental aspect of how the LGP changes from childhood to adulthood remains open. There are reasonable grounds to expect that children would rather exhibit a local advantage (see Section 2.4), but it is not clear how contingencies or masking would affect this population. The clinical and developmental aspects will be investigated in the next chapter.

Future studies could examine the effects of level, contingencies and masking with stimuli that are presented for even shorter durations and thus, outside participants' conscious awareness. For example, Paquet and Merikle (1984) used presentation times as low as 10ms. Potentially, the CE would be reduced if there was no conscious awareness of the stimuli and thus no strategic component in the CE.

To conclude, together, the three experiments have demonstrated that the GPE has perceptual and cognitive/strategic aspects. It is mandatory on the perceptual stage but can be manipulated on the cognitive level through contingencies/priming and implicit learning. However, even if attention is directed to the local level, the GPE has a strong impact on perception and can disturb the allocation of attention to local features. The GPE is likely based in the faster processing of global features compared to local features.

In the next Chapter, the results of a cross-sectional study with TD individuals and those with ASD who completed a selection of tasks from the current study will be presented.

# 8 Visual processing in typical and atypical development (VISTA)

In this chapter, the results of the study examining VISual processing in Typical and Atypical development will be presented (VISTA study). First, Section 8.1 will cover the findings in TD children, adolescents and adults, while in Section 8.2 visual processing in ASD will be thematised and compared with typical development. The chapter concludes with a discussion of limitations and overall summary of the results regarding visual processing in TD and ASD.

## 8.1 Local and global visual processing in typical development (TD)

### 8.1.1 Introduction

The experiments from the PECOG study in Chapter 7 demonstrated that the global precedence effect (GPE) was largely independent of the manipulated stimulus characteristics but it could be influenced by varying contingencies: With a higher percentage of local targets in a block the bias changed from a global bias towards a local one which was, at least to some extent, based on increased identity- and level-priming effects, and called the contingency effect (CE). Further, masking influenced the processing of local stimuli in that accuracy was significantly reduced in local trials with masked compared to unmasked targets in this sample of TD adults. Global trials, however, were unaffected, indicating that global features were likely to be processed first.

It is an open question whether and how these findings would be reflected in younger TD participants. In the current study, TD individuals from the age of 7 were examined with a selection of tasks from the PECOG study in order to determine typical developmental trajectories of local and global visual processing. Meanwhile, Section 8.2 covers participants that present atypical development with a diagnosis of ASD and compares them to this normative (age-matched) sample.

Previous research suggested predominantly that children have a local processing advantage that only later develops into a global advantage (Kimchi et al., 2005; Nayar et al., 2015; Neiworth et al., 2006; Poirel, Mellet, et al., 2008; Scherf et al., 2009; Scherf et al., 2008; Smith et al., 2011). Less consensus is found regarding the age at which this transition takes place or is completed, ranging from 7 - 9 years (Nayar et al., 2015; Poirel, Mellet, et al., 2008) to adolescence (Kimchi et al., 2005; Scherf et al., 2009;

Scherf et al., 2008). Based on the literature research (Chapter 2) we would argue that this depends firstly on the task at hand and its processing demand as well as its properties (e.g. less or more elements in a hierarchical task), and secondly, whether the tasks measure actual processing abilities or preferences. According to some researchers (e.g. Happe & Booth, 2008; Van Eylen et al., 2018), both local and global performance improve with age, indicating that they are not in an opposed relationship to each other but develop alongside. Potentially, previous findings of local biases in children reflected merely a processing preference and not an insufficient global processing ability. Processing *preferences* can be examined in tasks where attending the local or global level both lead to correct answers (free choice tasks). On the other hand, processing *abilities* can be measured if only one level carries the information necessary for a correct response.

Our experiments in the PECOG study (as well as the current study) included the latter type of task testing processing ability and supported the notion of an obligatory GPE on the perceptual level in TD adults which was, however, flexible and could be shifted based on the contingencies of local and global trials. The PECOG study further showed that adult participants showed reduced RTs to primed trials compared to when they had to switch processing levels between consecutive trials, as indicated by Priming Effects or Switch Costs (PESC). It was differentiated between level- and identity-priming. Findings of faster RTs for primed trials have repeatedly been reported by other researchers (e.g. Hayward et al., 2012; Hubner, 2000; Huizinga et al., 2010; Lamb et al., 2000; Lamb & Yund, 2000). However, in contrast to the PECOG study, Hayward et al. (2012) reported no significant PESC in the G50L50 condition (with 50% of trials with targets on the global and 50% of targets on the local level) in their sample of young adults. The ability to switch between processing levels has been suggested to improve with age showing developmental maturity (Huizinga et al., 2010); thus, it would be expected that children showed higher PESC than adults. In the current study, PESC were examined and compared between age groups and also between blocks with different stimulus presentation times and contingencies.

Interindividual differences apart from age have previously been reported: adults with higher amounts of autistic traits as measured by the Autism Spectrum Quotient (AQ, Baron-Cohen et al., 2001) have been shown to exhibit more local bias than those with less autistic traits (e.g. Crewther & Crewther, 2014; Cribb et al., 2016; Grinter et al., 2009; Van Boxtel & Lu, 2013), but effects on children have not yet been established. The relationship between autistic traits and processing biases across different age groups was examined in this study.

Participants aged 7 to 52 years completed five blocks of a hierarchical figures task adapted from the PECOG Study. One block was the standard condition with 50% of targets on either level (G50L50 or SHORT), two blocks had unequal contingencies (G20L80, G80L20), two further blocks had the standard contingencies but one had masked stimuli (MASK), and the other one long stimulus presentation times (LONG). With this selection of blocks, it was aimed to explore the GPE in this cross-sectional sample, its flexibility in different age groups, participants' ability to switch processing levels between trials as well as whether and how stimulus presentation times affected LGP. Lastly, all participants were asked to complete the AQ in order to examine the relationship between the amount of autistic traits and LGP.

On the whole, the following questions were addressed in this study:

- *Question 1: What is the developmental trajectory of processing biases from children over adolescents to adults?*

  Based on previous research (Kimchi et al., 2005; Scherf et al., 2009; Scherf et al., 2008) it was predicted that children would show a more local processing style compared to the older age groups, i.e. reactions to local targets would be faster than to global targets. The point in development at which global precedence takes over should be explored. It was expected to find a global bias in this TD sample due to the obligatory nature of the GPE which would show in the standard G50L50 condition with faster RTs in global trials compared to local trials.
- *Question 2: Can all age groups flexibly adjust their biases?*

  It was predicted that adults can successfully adjust their processing to the most appropriate level (e.g. Huizinga et al., 2010) which would be reflected in a robust CE. In children, due to the immaturity of the attentional system, the CE could be less pronounced.
- *Question 3: Do stimulus presentation times influence biases and are there any age differences?*

It was predicted that children would benefit from longer presentation times and therefore processing times, while shorter processing times (with masked stimuli) would impact their performance negatively (e.g. Kimchi, 2014). This would show in increased accuracy in the LONG condition, and reduced accuracy in the MASK condition compared to the standard SHORT condition. In adolescents and adults, the influence of stimulus presentation times was anticipated to be less pronounced. In PECOG, a negative effect of masking on accuracy in local trials was found which was in contrast to the findings of Hubner and Volberg (2005) and their Content Level Binding (CLB) Theory. It remained open whether or not the finding would be replicated in the current adult sample and younger participants.

- *Question 4: Are switch costs dependent on age, level, stimulus duration or contingency and are there different effects of level- and identity-priming?*

  It was predicted that all age groups could switch between levels on a trial-by-trial basis but that the ability to switch increases with age (Huizinga et al., 2010). This would be represented by higher PESC (i.e. higher RTs in trials with level-switch compared to level-priming or identity priming) in children compared to adult participants. Based on the PECOG study and in contrast to Hayward et al. (2012), PESC were also expected to be significant in adult participants. Also based on PECOG, it was predicted that RTs to identity primed trials would be slightly faster than those that were level-primed. No predictions were made regarding the influence of processing times, i.e. whether different PESC would be found in the blocks LONG, SHORT and MASK.

- *Question 5: Do TD participants show more local bias if they score high on the AQ and are there any differences between younger and older participants?*

  Based on previous research it was predicted that adults with more autistic traits (higher AQ scores) would show better local processing and less GPE (Almeida, Dickinson, Maybery, Badcock, & Badcock, 2013; Happe et al., 2001; Van Boxtel & Lu, 2013). This could potentially be found in a correlation approach but more likely in an extreme groups approach comparing the processing biases between participants with higher and lower AQ scores (Cribb et al., 2016;

Grinter et al., 2009). No prediction was made regarding the influence of autistic traits in children.

### 8.1.2 Method

#### 8.1.2.1 Subjects

Originally, 73 participants took part in the experiments; however, five were later excluded due to a diagnosis of a learning disability (dyslexia, dyscalculia, dyspraxia). The data from 68 participants aged 7 to 52 (*M* = 17.40, *SD* = 9.7) are included in this study (38 females, 30 males). The average verbal performance (VP) score for the participants was 67.5 (*SD* = 8.3), non-verbal performance (NVP) score 57.0 (*SD* = 7.1), full-scale IQ (FSIQ) 122.1 (*SD* = 12.3) and AQ 53.3 (*SD* = 12.0). Please see Table 8.1 for a more detailed sample description.

Table 8.1

*Sample characteristics of the TD sample*

| Group | n | Age *M(SD),* [range] | Gender (f:m) | VP | NVP | FSIQ | AQ |
|---|---|---|---|---|---|---|---|
| Children | 21 | 9.3 (1.1) [7.6-11.1] | 12:9 | 73.8 (5.9) [64-80] | 60.2 (6.8) [38-70] | 131.1 (10.7) [101-147] | 52.3 (11.9) [21-70] |
| Adolescents | 23 | 14.9 (1.8) [12.7-17.8] | 13:10 | 63.9 (9.5) [42-79] | 53.5 (6.6) [38-62] | 115.4 (12.2) [86-138] | 53.5 (13.2) [26-73] |
| Adults | 24 | 26.8 (10.7) [18.2-52.8] | 13:11 | 65.9 (5.8) [53-75] | 57.4 (6.5) [47-69] | 120.5 (8.8) [108-137] | 53.9 (11.2) [33-74] |

*Note.* For age, VP, NVP, FSIQ and AQ means, SD and ranges are given. VP and NVP are given as standard scores (*M* = 50, *SD* = 10). The AQ was scaled on 0-3 for all age groups for comparability. Original scoring of adolescent and adult samples gave values for adolescents of *M(SD)* = 15.6(4.8), range [8, 25] and adults *M(SD)* = 14.1(4.7), range [5, 23]. AQ cut off scores: children = 76, adolescents = 30 (original scoring), adults = 32 (original scoring). No TD scored above the AQ cut-off scores.

#### 8.1.2.2 Procedure

Participants completed the VISTA experiments as part of the larger language and perception study (VISTA + LANTA). The order of tests can be seen in the participants' certificate in Appendix F). The experimental blocks were intertwined with language tasks (LANTA study) and the WASI subtests.

Participants completed the following visual tasks as described in Section 6.4: CONTI (3 blocks: G20L80, G50L50, G80L20), MASK (1 block) and LONG (1 block). Each block consisted of 80 trials.

In G20L80, G50L50 and G80L20 the target stimuli (hierarchical figures) were visible for 150ms with 20% global, 80% local targets (G20L80), 50% each (G50L50), and 80% global, 20% local targets (G80L20). The G50L50 condition also served as the SHORT condition in the analysis of stimulus duration effects. In MASK, there were 50% global and 50% local targets, all visible for 150ms followed by a 50ms mask. In LONG, 50% global and 50% local targets were visible for up to three seconds or until the participants gave their response. One button indicated diamond as the target, another one square. Targets were on either the local level (small elements) or on the global level (overall picture). The exact order of blocks was counterbalanced across participants.

#### 8.1.2.3 Analysis

The data from the five blocks were analysed aiming to answer the research questions as described in Section 8.1.1. In general, the RT were analysed for differences between conditions and age groups. Further, Bias Indicators (BI, see Appendix A for formulas) were calculated. RTs and BIs were analysed by means of repeated measures ANOVAs (see Table 8.2). ANOVA Factors and levels can be seen in Table 8.3. The $BI_{RT}$ and $BI_{ACC}$ (if applicable) were further tested for significance per se (e.g. in the different age groups or blocks) with one-sample t-tests (test-value 1, as BI =1, indicates no significant bias; BI < 1: global bias; BI > 1: local bias).

ACC data were mostly at ceiling: depending on the experimental block, between 37.5% and 61.4% of participants achieved 100% accuracy (means ranged between 93% and 97% accuracy, medians ranged between 97.5% and 100%). Thus, there was not enough variance in the accuracy data in order to assess reliable effects of target level or CEs. Accuracy data for TD will therefore only be reported for the analyses including masking and PESC (where accuracy was more variable). No speed-accuracy trade-off was found in the data ($p > .05$).

The results will be reported and discussed in separate sections for each experimental task/research question. Descriptive tables and detailed statistical results can be found in Appendix G. In the text, only *p*-values of significant main effects or interactions will be provided.

Table 8.2

*Summary of research questions, IVs, DVs and statistical analyses in the VISTA study*

| Questions addressed | 1, 2 | | 3 | | 4 | | 5 |
|---|---|---|---|---|---|---|---|
| Blocks | G50L50, G20L80, G80L20 | | SHORT (G50L50), LONG, MASK | | LONG, SHORT (G50L50), MASK, G20L80, G80L20 | | G50L50, LONG, MASK |
| DV | RT | $BI_{RT}$ | RT, ACC | $BI_{RT,}$ $BI_{ACC}$ | RT, ACC | PESC | |
| IV | Level, age group, contingency | Age group, block | Level, age group, duration | Age group, duration | Block[a], level, priming, age group | Block[a], level, age group | $BI_{RT}$, AQ |
| Test | 2x3x3 ANOVA | 3x3 ANOVA | 2x3x3 ANOVA | 3x3 ANOVA | 3x2x3x3 ANOVA | 3x2x3 ANOGA | Correlation, EGA |

*Note.* DV: dependent variables, IV: independent variables, PESC: Priming Effects/Switch Costs, AQ: Autism Quotient, EGA: Extreme Group Approach.
Footnote a: Two analysis were conducted: with blocks of different stimulus durations, and with blocks of different contingencies. *Question 1*: What is the developmental trajectory of processing biases from children over adolescents to adults? *Question 2*: Can all age groups flexibly adjust their biases? *Question 3*: Do stimulus presentation times influence biases in LGP and are there any age differences? *Question 4:* Are switch costs dependent on age, level, stimulus duration or contingency and are there different effects of level- and identity-priming? *Question 5*: Do TD participants show more local bias if they score high on the AQ and are there any differences between younger and older participants?

Table 8.3

*Factors and their levels in the repeated measures ANOVA used in the VISTA study*

| Factor | Levels |
|---|---|
| Level | Global, local |
| Contingency | 20%, 50%, 80% (only 50% and 80% for switch cost analysis) |
| Block | G20L80, G50L50, G80L20 |
| Duration | LONG, SHORT, MASK |
| Priming | Switch, level-priming, identity priming -- Or for PESC: primed, nonprimed |
| Age Group | Child, adolescent, adult |
| Sample Group | ASD, AmTD |

*Note.* PESC: Priming Effects/Switch Costs; AmTD: age-matched TD.

### 8.1.3 Q1-3: Perception Bias, its flexibility and the influence of stimulus presentation times

This section examined processing biases in children, adolescents and adults, whether they could be overcome by a manipulation of the contingencies and whether stimulus presentation times influences LGP.

#### 8.1.3.1 Results Q1&2: Perception Bias and its flexibility

*Summary of Results:* The analysis showed that TD participants of all age groups had a global bias with faster RTs to global than local trials in the standard G50L50 condition. In all groups, a shift of the bias due to different contingencies was found, although it was less pronounced in children.

Descriptive Tables can be found in Appendix G.1.1.1 (for RTs Table *G.2*, accuracy Table *G.3*) and G.1.1.3 (for BIs, Table *G.12*). Tables with the inferential statistics can be found in Appendix G.2.1. (Table *G.28* and Table *G.29*).

##### *8.1.3.1.1 Reaction Times (*Table G.28*)*

A 2x3x3 repeated-measures ANOVA with factors level, contingency and age group revealed no significant interactions between factors ($p > .05$), but significant main effects of level ($p < .001$), age group ($p < .001$), and contingency ($p < .001$). RTs were faster for global ($M = 717$ms) than local targets ($M = 767$, see also Figure 8.1). Children ($M = 932$ms) were slower than adolescents ($M = 662$, $p < .001$) and adults ($M = 625$, $p < .001$) who were comparable ($p = 1$). Collapsed across age groups, there was no significant difference between the 20% and 50% contingency condition ($p = 1$), but between the 50% and 80% condition ($p < .001$, see Figure 8.2). The interaction Level x Age Group was not far from significant ($p = .090$).

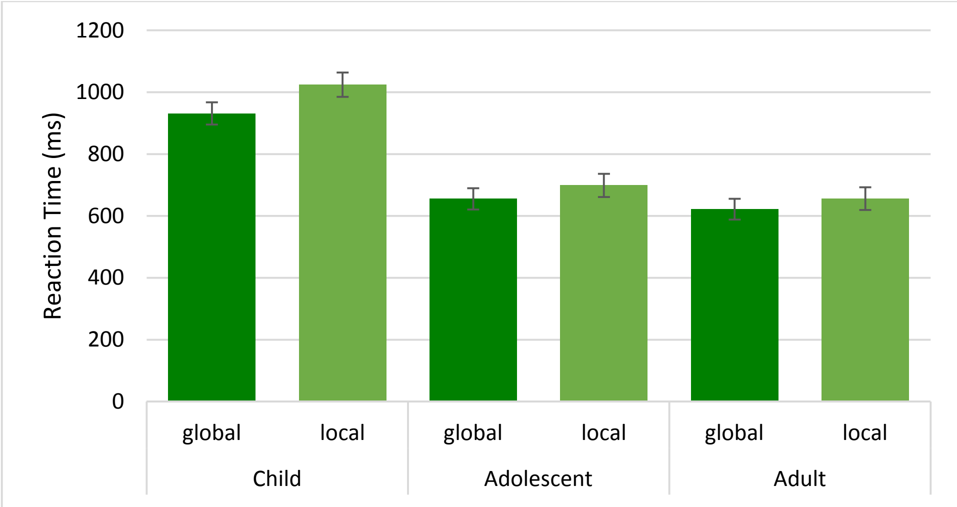



*Figure 8.1.* RTs to global and local targets in each TD age group.
Group means and standard errors are displayed. Overall, RTs to global targets were faster than to local. Children's RTs were slower than those of the older groups.

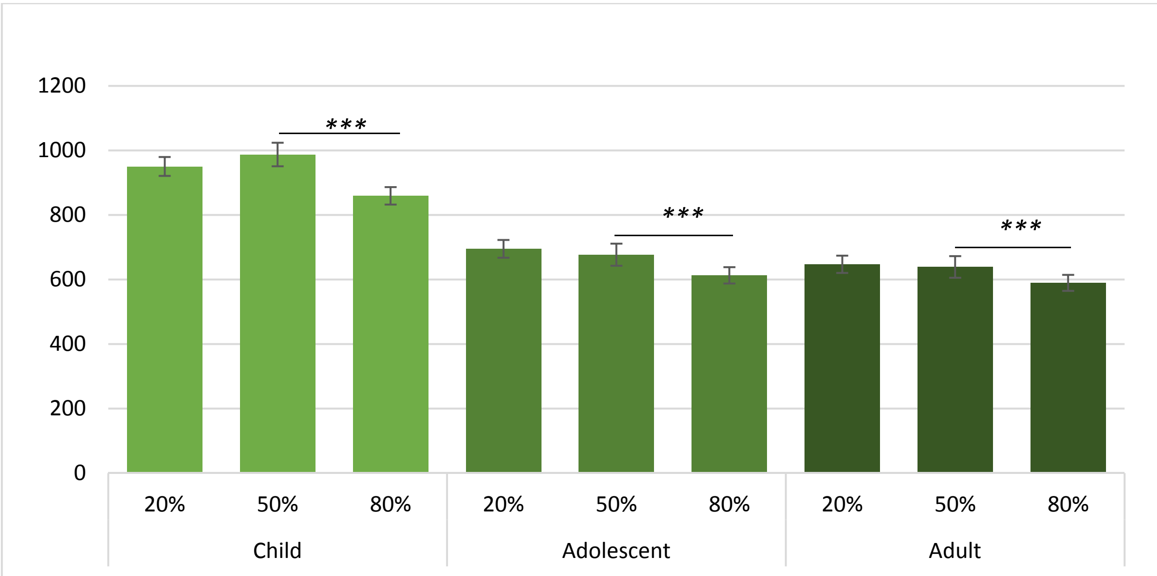



*Figure 8.2.* RTs in different contingencies (20%, 50%, 80%) within TD age groups.
Local and global targets are combined. Error bars represent standard errors. *** indicate significance of differences between contingencies ($p \leq .001$).

#### *8.1.3.1.2 Bias Indicator ($BI_{RT}$, Table G.29)*

A 3x3 repeated measures ANOVA (Block x Age Group) with the DV Bias Indicator $BI_{RT}$ revealed that block was a significant main effect ($p$ < .001), whereas the interaction Block x Age Group was not significant ($p$ = .590). The main effect of age group also did not reach significance ($p$ = .100).

Across groups, there was a significant reduction of the $BI_{RT}$ from the G20L80 to the G50L50 to G80L20 block (but not in children from G50L50 to G80L20, see Table 8.4). The $BI_{RT}$ was significantly different from 1 (no bias) in all age groups and blocks, except for the G20L80 block in children, $t(19) = 1.304$, $p = .208$ (see Figure 8.3).

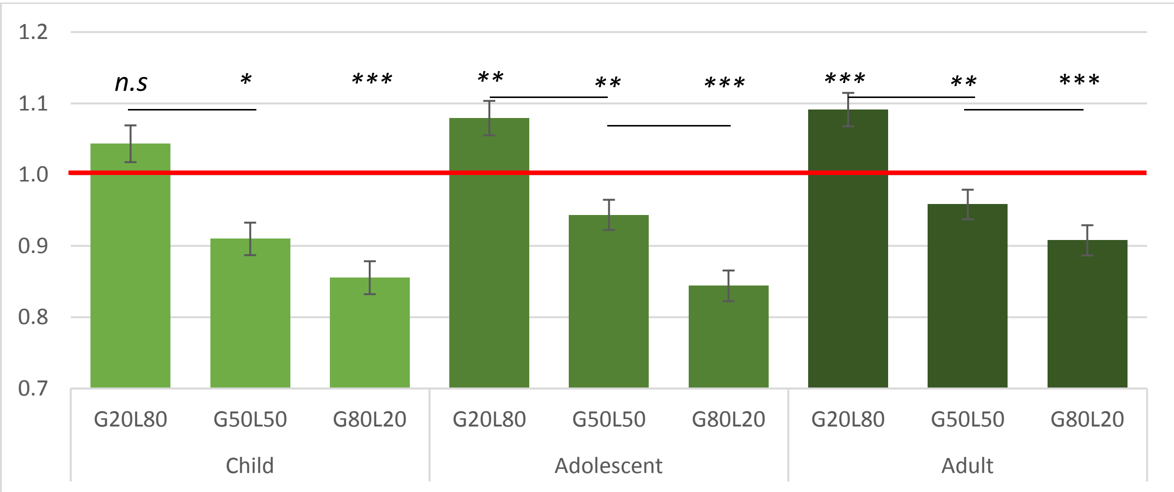



*Figure 8.3.* Bias Indicator $BI_{RT}$ per contingency block per TD age group.
The line indicates BI = 1: no bias; BI < 1: global bias; BI > 1: local bias. Stars indicate level of significance in one-sample t-tests against test value 1. *: $p \leq .05$; **: $p \leq .01$, ***: $p \leq .001$. ― indicate significant pairwise comparisons (see also Table 8.4).

Table 8.4

*Results of the pairwise comparisons testing differences in the BIRT between blocks with different contingencies in VISTA*

| | | G20L80 vs G50L50 | | | G50L50 vs G80L20 | | |
|---|---|---|---|---|---|---|---|
| | | *t* | *p* | *d* | *t* | *p* | *d* |
| child | *df* = 19 | 4.289 | <.001 | .959 | 1.258 | .224 | .281 |
| adolescent | *df* = 22 | 6.325 | <.001 | 1.319 | 4.558 | <.001 | .950 |
| adult | *df* = 23 | 5.627 | <.001 | 1.149 | 2.991 | .007 | .611 |

*Note.* Bonferroni-corrected alpha-level α = .025. *d*: effect size.

#### 8.1.3.2 Results Q3: The influence of stimulus presentation times on LGP

As LONG was only introduced as a separate condition after the first 20 TD children were tested, the analyses including LONG are only based on 13 child, 12 adolescent and 23 adult participants. In order to use all available data (20 children, 23 adolescents, 23 adults), the analysis was repeated with only the blocks SHORT and MASK and will be reported if results differed from the analysis with three blocks. RT data, as well as accuracy data, were included to examine effects of stimulus durations.

*Summary of results*: The analyses showed that stimulus durations did not influence biases but overall RTs. The longest RTs were found in MASK. In children, there was a tendency of increasingly more global bias with shorter processing times.

Descriptive Tables can be found in Appendix G.1.1.1 (for RTs Table *G.2*, accuracy Table *G.3*) and G.1.1.3 (for BIs, Table *G.12*). Tables with the inferential statistics can be found in Appendix G.2.2. (Table *G.30* and Table *G.31*).

##### *8.1.3.2.1 Reaction Times (*Table G.30*)*

The 3x2x3 repeated measures ANOVA (Duration x Level, x Age Group) revealed as in the previous analyses a significant main effect of age group *(*$p < .001$). As before, children had the slowest RTs ($p < .001$) followed by adolescents and adults who did not differ ($p = .314$). Further, the main effect of duration was significant ($p = .001$). RTs in the condition SHORT ($M = 767$ms) were comparable to LONG ($M = 776$ms, $p = .650$), but both were significantly faster than those in MASK ($M = 841$ms, $p \leq .01$). There were no significant interactions ($p > .05$). Level was a significant main effect, ($p < .001$), with global RTs ($M = 767$ms) being faster than local ones ($M = 822$ms). Similar results were found when only SHORT and MASK were included in the analysis.

##### *8.1.3.2.2 Bias Indicator ($BI_{RT}$,* Table G.31*)*

No significant effects were found when examining the $BI_{RT}$ with a 3x3 repeated measures ANOVA with the factors duration and age group (all $p > .05$).

Although no significant interactions were found in the RT data, and no significant effects were found in the BI data, the $BI_{RT}$ was not significantly different from 1 (no bias) in all duration conditions and age groups (but some were nearly significant, see Table 8.5 and Figure 8.4). In children and adults, the global bias was only significant in the SHORT condition, but not the LONG and MASK condition. In adolescents, the $BI_{RT}$ was significantly lower than 1 in SHORT and MASK but not LONG.

#### *8.1.3.2.3 Accuracy (*Table G.30*)*

A 3x2x3 repeated measures ANOVA (Duration x Level x Age Group) revealed a significant main effect of age group ($p$ = .016) but no other significant main effects or interactions. Children had the lowest accuracy overall ($M$ = 92.3%) followed by adolescents ($M$ = 96.6%, $p$ = .011) and adults ($M$ = 97.2%, $p$ = .009) who did not differ ($p$ = .765, cf. Figure 8.5).

Table 8.5

*Results for the test for a significant perception bias (one-sample t-test with test value BIRT = 1) in VISTA*

| | long | | | short | | | mask | | |
|---|---|---|---|---|---|---|---|---|---|
| | t | p | d | t | p | d | t | p | d |
| child | -1.226 | .246 | -.354 | -2.804 | .011* | -.612 | -2.027 | .056 | -.442 |
| adolescent | -1.477 | .168 | -.426 | -2.936 | .008* | -.612 | -4.076 | .001* | -.850 |
| adult | -2.017 | .056 | -.420 | -2.780 | .011* | -.601 | -1.653 | .112 | -.336 |

*Note. d*: effect size. Children: $df_{long}$ = 11, $df_{short}$ = 20, $df_{mask}$ = 20; Adolescents: $df_{long}$ = 11, $df_{short}$ = 20, $df_{mask}$ = 22; adults: df = 22. * indicates significant biases.

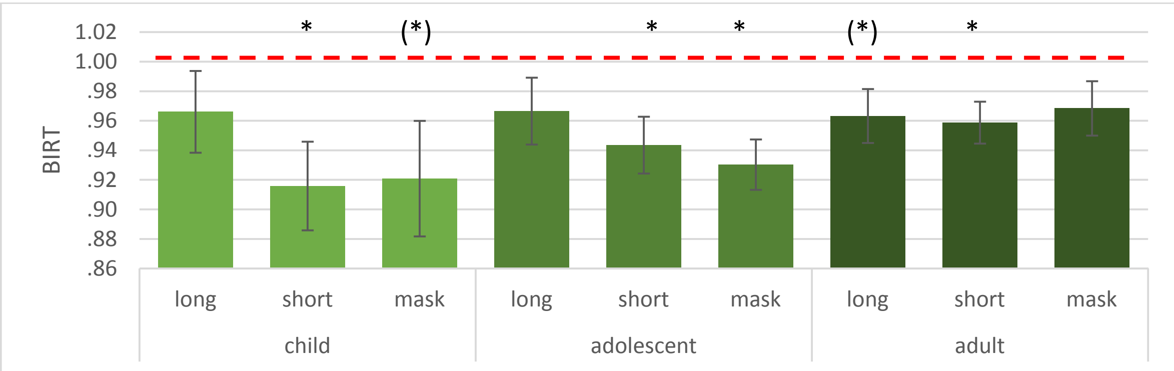



*Figure 8.4.* Means and SE of $BI_{RT}$ for each TD age group and duration condition.
*: $p \leq .05$, (*): $p \leq .1$ for test of bias significance ($BI_{RT} \neq 1$). Children $N_{long}$ = 12, $N_{shor}$t and $N_{mask}$ = 21; Adolescents $N_{long}$ = 12, $N_{short}$ and $N_{mask}$ = 23, Adults N = 23

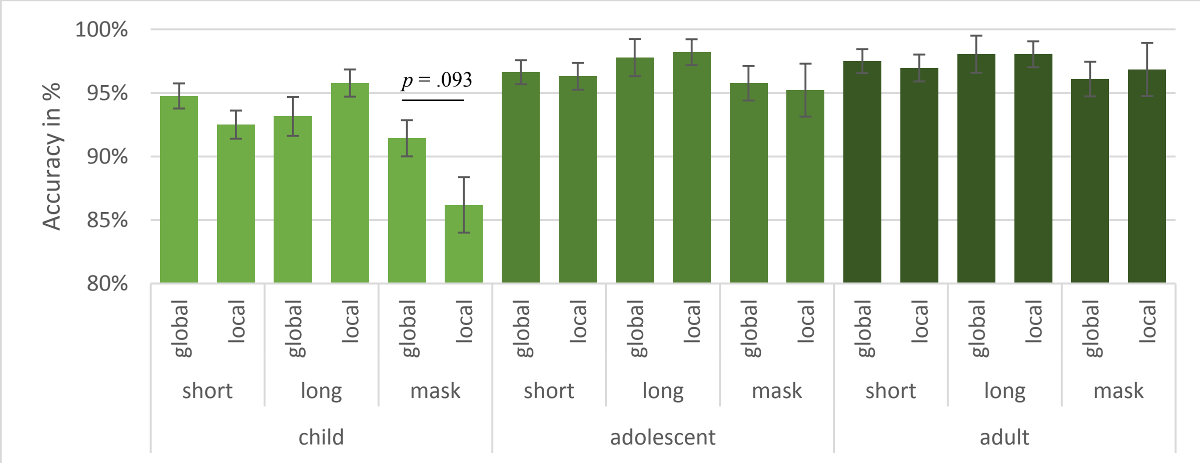



*Figure 8.5.* Accuracy data for each TD age group level and duration.
M and SE are shown. Accuracy between local and global targets did not differ significantly ($p > .05$).

When only the conditions SHORT and MASK were included in the analysis (and thus more participants), there was also a significant interaction of Duration x Age Group ($p = .046$). Post-hoc t-tests showed that in children, accuracy was significantly reduced in MASK ($M = 88.8\%$) compared to SHORT ($M = 93.6\%$, $p = .006$). In the other age groups, the difference between those blocks was not significant ($p > .4$). The reduced accuracy in MASK in children was mainly due to lower accuracy for local trials (cf. Figure 8.5).

### *8.1.3.2.4 Bias Indicator ($BI_{ACC}$,* Table G.31*)*

In the $BI_{ACC}$, the 3 x 3 ANOVA (Duration x Age Group) revealed a nonsignificant main effect of age group ($p = .681$). The main effect of duration ($p = .064$) and the interaction Duration x Age Group were not far from significant ($p = .059$) and the interaction was explored further. As can be seen in Figure 8.6, in children the $BI_{ACC}$ appeared to be higher in the LONG condition compared to SHORT (only descriptively, $p > .05$) and MASK ($p = .038$). In none of the conditions the $BI_{ACC}$ was actually significantly different from 1, thus there was no significant bias regarding accuracy data.

Including only the SHORT and MASK conditions lead to similar results.

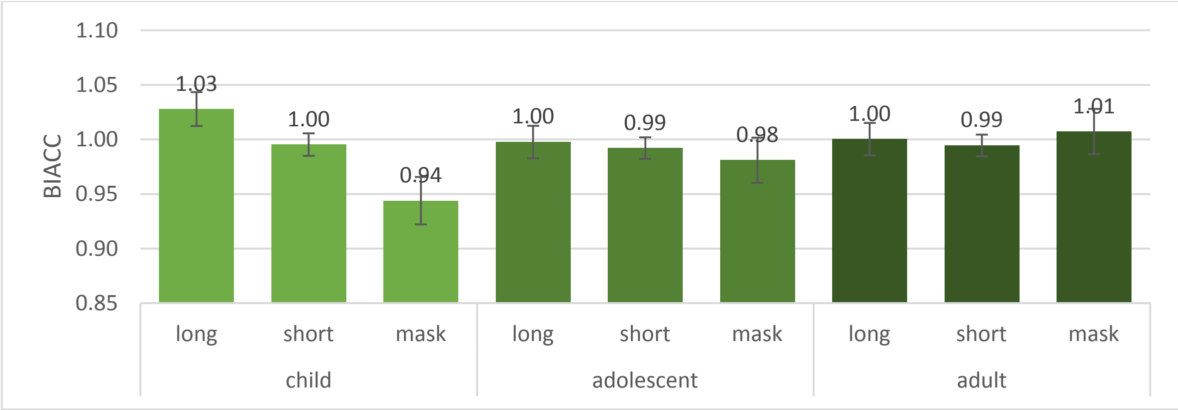



*Figure 8.6.* $BI_{ACC}$ in different duration conditions in TD age groups.
Note that no $BI_{ACC}$ was significantly different from 1, i.e. there were no significant biases and they did not differ between conditions.

#### 8.1.3.3 Summary and Discussion

##### *8.1.3.3.1 Q1: What is the developmental trajectory of processing biases from children over adolescents to adults?*

As expected, a global bias could be found in this sample of TD adults with faster RTs to global compared to local trials in the standard G50L50 condition. Moreover, the other age groups also exhibited a global bias in this condition and no significant group differences were found, although descriptively children had the most pronounced global bias. The priming analysis that will be presented in the next Section 8.1.4 also showed a global advantage in children regarding accuracy (see page 157), although the common assumption/finding is that children have a local bias or processing advantage (cf. Kimchi, 2014; Kimchi et al., 2005; Mottron et al., 2000; Oishi et al., 2014; Scherf et al., 2009; Scherf et al., 2008). The crucial variable might be the age of the children, as researchers suggested different age ranges for when a local advantage changes into a more adult-like global preference: Although some researchers suggested adolescence (Kimchi et al., 2005; Scherf et al., 2009; Scherf et al., 2008), Nayar et al. (2015) determined the age as between 4 and 7 years; thus, younger than our child sample (which had a range 7-11, $M$ = 9 years). Poirel, Mellet, et al. (2008) on the other hand suggests the age of 9 years. Potentially, the transition to a global processing advantage had already taken place in (most of) the current child participants, thus, before the age of 8 years, Huizinga et al. (2010) explored global and local processing throughout development, especially in regards to the ability to shift attention from one level to the other. Alternatively to the above explanation, according to Huizinga et al. (based on Werner's orthogenetic principle, 1957), it is not that children have a local advantage and adults a global one. Instead, global processing precedes detailed local processing not only in the microgenetic level of development (i.e. the order in which information is processed) but also the epigenetic level of development (i.e. the development through life); thus, children would exhibit a global advantage and local processing would only become more sophisticated later in life. Similar had been suggested by Niaz (1987, cf. Section 2.4). Based on these considerations, it would be expected to find a global bias in children which could be even stronger than in adults. The current RT data support this notion, although only on the descriptive level. Regarding accuracy, a global bias in children was found.

Despite the repeated findings of different processing styles in children vs. adults, meta-analyses concluded that age was not a significant moderator when analysing LGP abilities (Muth et al., 2014; Van der Hallen et al., 2015).

Interestingly, however, children showed a tendency towards a local bias ($BI_{ACC}$) in the LONG condition ($BI_{ACC}$ = 1.03 but n.s.). The variance in this age group was relatively large (*SD* = .13), showing that there were notable interindividual differences: 4 children had a global bias, 5 no bias and 3 a local bias. Potentially, when children have a choice (i.e. when the stimuli were displayed for a long time like in LONG), local processing might be preferred in some children resulting in more accurate local performance, although global processing is more efficient in conditions that rely on more automatic processing (SHORT, MASK). (Some) children might have a (voluntary) local processing preference when given the option although their automatic (involuntary) processing is still directed towards global precedence. Accordingly, Poirel, Mellet, et al. (2008) found that children aged 4 had a local preference, while those aged 9 had a global preference. Further, Wang et al. (2007) also found that the global bias reduced in TD children with longer presentation times. Apparent contradictions in the research with some studies showing a local advantage, others a global advantage in child participants can thus be explained by specific task parameters (e.g. stimulus presentation duration, free choice task) and sample characteristics (e.g. individual processing preferences, age). On the whole, based on previous and the current research, we suggest that processing abilities on both levels increase with age, but the preference changes from local in young children (aged 7-11) to global in older participants (cf. Figure 8.7).

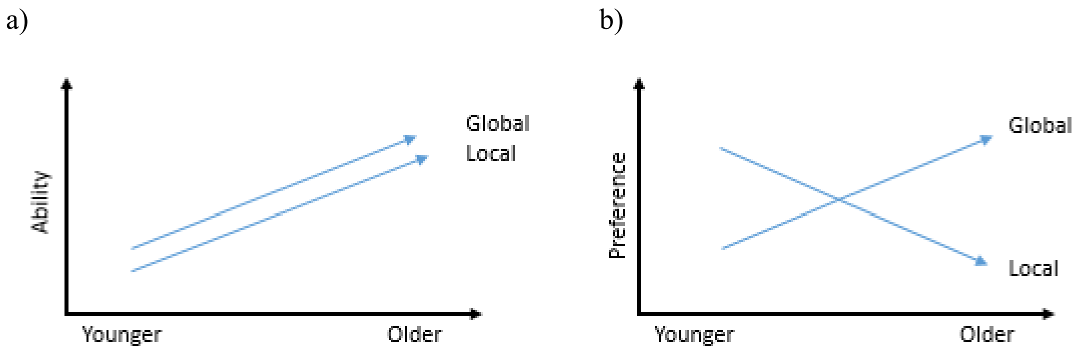



*Figure 8.7.* Suggested developmental trajectories for local and global processing.
a) both local and global processing abilities increase with age), b) processing preference changeds from the local to the global level.

### *8.1.3.3.2 Q2: Do stimulus presentation times influence biases in LGP?*

The first finding regarding different presentation times was that RTs varied slightly between duration conditions, with SHORT and LONG being associated with quicker responses than MASK. From observation as well as comments from participants (especially children), they often felt they had to *think more about what they had seen* in MASK leading to slower responses. This could explain the small variation in RTs between conditions.

Although biases ($BI_{RT}$) varied slightly between duration conditions, there were no specific significant effects of duration or age. There was a tendency for less global bias in longer exposure times which is equivalent to Wang et al. (2007).

In regards to accuracy, in the PECOG study, it was found that in adults the $BI_{ACC}$ was lower (more global bias) with masking ($BI_{ACC}$ = .92) compared to without ($BI_{ACC}$ = .97), possibly because local processing has a longer time-course than global (cf. eg. Kimchi, 1998; Navon, 1981; Paquet & Merikle, 1984; Scherf et al., 2008) and, therefore, was not completed yet when the mask appeared, leading to reduced accuracy in local trials. Based on those findings, it could have been expected that masking would also affect local processing in the current adults in MASK. However, this was not replicated in the current study where masking did not have any significant effects in adults or adolescents. This finding is in accordance with the CLB Theory by Huber and Volberg (2005, see Section 7.5.3 for more information). In children, masking reduced accuracy overall with a tendency of lower accuracy in local than global trials. Thus, reduced processing times impacted the child group more than the older groups, and it impacted the local level more than the global level.

While the $BI_{ACC}$ did not differ much between conditions in the adolescents and adults, it was, at least on the descriptive level, influenced by stimulus duration in children. With longer presentation times, children appear to be better able to perceive also the local forms (potentially due to a processing preference) which led to reduced global bias (even with a tendency of a local bias, $BI_{ACC} = 1.03$). However, overall, there was no significant bias in accuracy in any duration condition or age groups (BI $\neq 1$: n.s). This could be because the task was too easy for most participants leading to little variance in the accuracy data between local and global trials.

*8.1.3.3.3 Q3: Can all age groups flexibly adjust their biases?*

According to the predictions, all age groups showed varying processing biases depending on the contingencies of local and global trials in a block, showing the CE. Although the PECOG Study showed a reduced CE on the local level, in the current TD participants local and global processing benefited comparably from increased contingencies.

The analysis of the $BI_{RT}$ drew a similar picture in adolescents and adults: a significant local bias in G20L80, global bias in G50L50, and increased global bias in G80L20. In children, however, there was no significant local bias in G20L80. Further, the difference in $BI_{RT}$ between G50L50 and G80L20 was not significant, either because the bias was already relatively high in G50L50 or because the increased contingency in G80L20 did not provide children with much more benefit. Huizinga (2010) argue that the ability to switch between levels improves with maturity; therefore, adults are able to select the most appropriate processing level depending on the task at hand. It appears that adolescents and adults in the current study were able to increasingly focus attention on the local level in the G20L80 condition, while children were not sufficiently able to. They did, however, adjust their attention partially and overcame the global bias (in G20L80) but this only resulted in no significant bias at all.

In sum, the results supported Huizinga et al.'s (2010) account that local processing takes more time on the microgenetic level (i.e. the global level is processed first) as well as epigenetic level (i.e. global processing becomes sophisticated earlier in life than local processing) and that the ability to switch between processing levels and selecting the most appropriate one develops with age. Switching between levels was analysed in more detail on a trial-by-trial basis in the next section.

### 8.1.4 Q4: Effects of Age, Level, Stimulus Duration and Contingency on Switch Costs

This section examined the influence of priming on LGP and whether there were differences in priming depending on age, processing level, stimulus duration and contingencies.

#### 8.1.4.1 Results

Similarly to the previous analysis, the data was analysed twice, once with the block LONG (with missing data) and once without. The results from the analyses including only SHORT and MASK will be reported if they differed from the analysis with three blocks. Significant main effects or interactions will only be reported if they involve priming, as other factors have been covered in previous analyses.

*Summary of results:* Overall, the PESC analysis showed that processing level, stimulus duration and contingencies did not have much influence on the ability to switch between levels. In children switching was associated with higher $PESC_{RT}$ than in the older participants, as well as higher $PESC_{ACC}$ when switching from local to global after stimuli were visible for a long time.

Descriptive Tables for RTs and accuracy can be found in Appendix G.1.1.2 (Table *G.4* to Table *G.11*). Tables with the inferential statistics can be found in Appendix G.2.3 and G.2.4 (Table *G.32* to Table *G.33*Table *G.34*).

##### *8.1.4.1.1 Stimulus Duration and Priming*

*Reaction Times and Accuracy (*Table G.32*)*

In the 3x2x3x3 repeated measures ANOVAs (Duration x Level x Age Group x Priming) with the DV RT, the main effect of priming was significant ($p < .001$). RTs in trials with switch priming were highest ($M$ = 831ms), followed by those with level-priming ($M$ = 775ms) and lastly identity-priming

($M$ = 744ms, all $p$ = .004). The interaction of Priming x Age Group was significant ($p$ = .043). Further exploration of this interaction showed that in children and adolescents RTs to level- and identity priming did not differ significantly ($p$ = 1 and $p$ = .093 respectively), whereas they did in adults ($p$ = .041). Other interactions with the factor priming were nonsignificant.

In terms of accuracy, the 3x2x3x3 ANOVAs (Duration x Level x Age Group x Priming) revealed only a significant main effect of priming ($p$ < .001). Accuracy was lowest in switch trials ($M$ = 92.3%), and higher for level-priming ($M$ = 95.1%, $p$ < .001) and identity-priming ($M$ = 95.9%, $p$ < .001), whereas the priming conditions did not differ ($p$ = .595).

When only two durations (SHORT and MASK) were included in ANOVAs, the results were comparable.

*Priming Effects / Switch Costs (PESC,* Table G.33*)*

$PESC_{RT}$ were analysed in a 3x2x3 ANOVA (Duration x Level x Age Group) which revealed only a significant main effect of age group ($p$ = .012). Pairwise comparisons showed that $PESC_{RT}$ in children ($M$ = 97ms) were significantly higher than in adolescents ($M$ = 55ms, $p$ = .034) and adults ($M$ = 58ms, $p$ = .022), whereas adolescents and adults did not differ ($p$ > .05). The results did not change when the analysis was repeated without the block LONG.

In the 3x2x3 ANOVA with the DV $PESC_{ACC,}$ the interaction of Duration x Level x Age Group was significant ($p$ = .049). Other main effects or interactions were not significant. Post-hoc tests showed that in children the difference between global ($M$ = 6.5%) and local $PESC_{ACC}$ ($M$ = 0.1%) in LONG was significant ($p$ = .0496), whereas in other durations and age groups $PESC_{ACC}$ for local and global were comparable ($p$ > .370, see also Figure 8.8). As apparent in Figure 8.8b, this result can be interpreted as higher switch costs when participants had to switch from local to global levels or as a higher priming effect in global trials, whereas accuracy in local trials was not influenced by prime condition. Either way, it is evident that priming did not affect local processing in children.

The results for $PESC_{ACC}$ did not change when the analysis was repeated without the duration LONG, except that the mentioned 3-way interaction above was no longer significant ($p$ = .749).

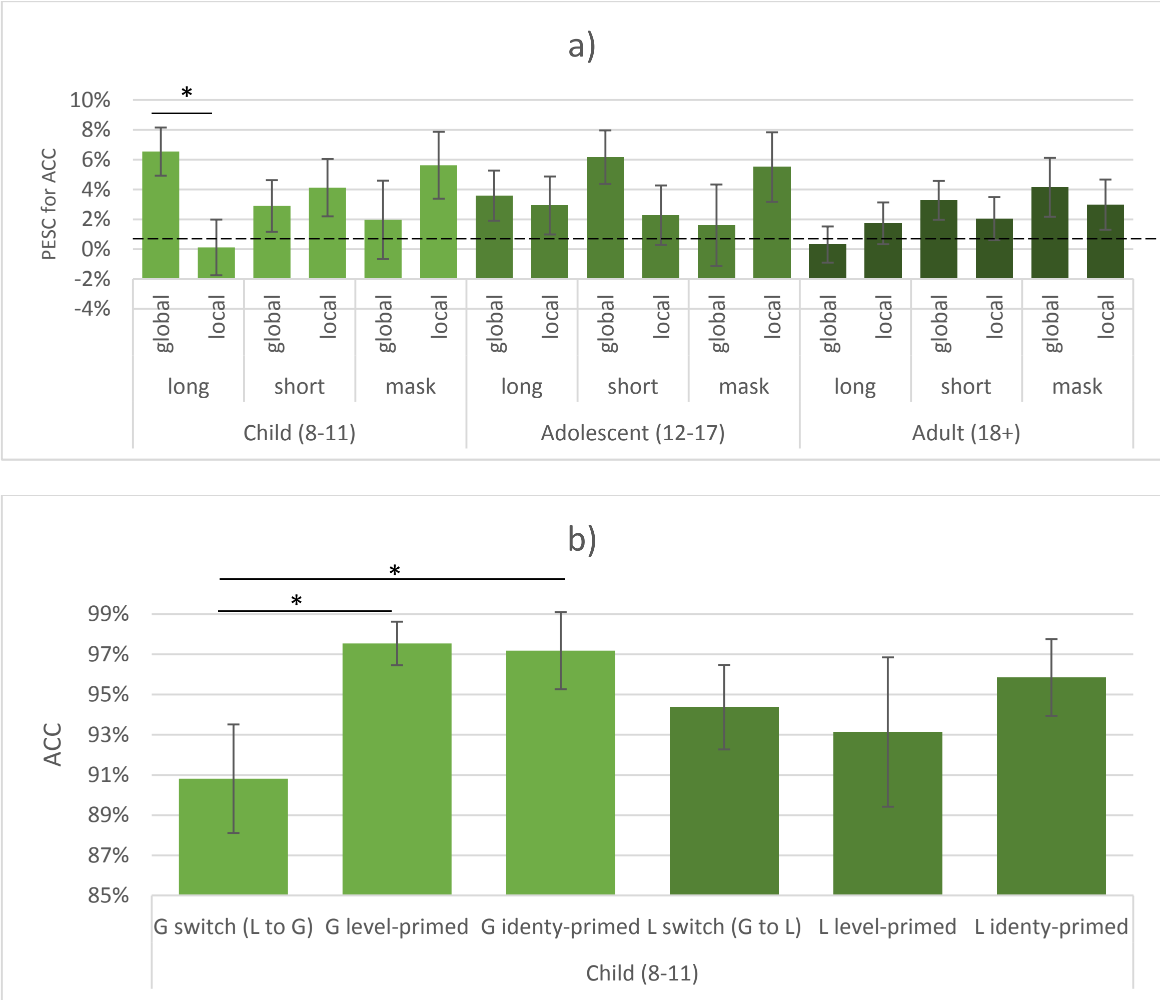



*Figure 8.8.* Visualisation of $PESC_{ACC}$ and accuracy in the TD sample.
A) Visualisation of the interaction between duration, level and age group. B) Further examination of the significant differences in children in the duration LONG. Means and SE are displayed.* indicate significant differences.

#### *8.1.4.1.2 Priming and Contingencies*

*Reaction Times (*Table G.34*)*

Equivalently to the PECOG study, the interaction between priming and contingencies was examined by analysing the effect of level-switch, identity- and level-priming in the blocks G20L80, G50L50 and G80L20. Only the contingencies of 50% and 80% were included, as the 20% contingency did not have enough primed trials to examine effects reliably.

A 2x2x2x3 repeated measures ANOVA with the factors level, contingency (50, 80%), priming, and age group showed as in the previous analyses a significant main effect of priming ($p < .001$): RTs were fastest with identity-priming (*M* = 695ms), followed by level-priming (*M* = 728ms), and level-switching (*M* = 781ms). No other effects of priming or its interactions were found.

*Accuracy (*Table G.34*)*

The accuracy analysis showed a similar pattern to the RT analysis: The 2x2x2x3 repeated measures ANOVA with the factors level, contingency (50, 80%), priming, and age group revealed that the main effect of priming was significant ($p < .001$): accuracy were lowest after level-switch (*M* = 92.8%), followed by level-priming (*M* = 95%) and identity priming (*M* = 95.7%), while the two priming conditions did not differ. Further, the main effects of contingency ($p = .048$) and age group ($p < .001$) were significant as well as the interaction of Level x Age Group ($p = .032$). Children showed less accuracy in local trials (*M* = 88.2%) compared to global trials (*M* = 93.9%). Accuracy in local and global trials did not differ in the other age groups ($p > .05$).

#### 8.1.4.2 Summary and Discussion

A more in-depth analysis of the raw data allowed to examine effects of level-switching (e.g. the target level is first local and then global in the following trial), level-priming (e.g. the target is a global diamond and then a global square in two consecutive trials), and identity-priming (e.g. the target is a global diamond in two consecutive trials) on RTs and accuracy. Firstly, all age groups performed better in primed compared to nonprimed trials and showed increased RTs and reduced accuracy when level-switch was required. The extent of PESC varied between age groups: children showed higher PESC in RT and accuracy (but for accuracy only in the LONG condition), thus more difficulty to switch between levels than adolescents or adults (or more benefit from priming), which is in line with Huizinga's (2010) claim that the ability to switch between levels develops with age. Based on the PECOG study, it was expected to find significant PESC in adult participants (which was in contrast to Hayward et al.'s (2012) findings), and that identity priming would lead to lower RTs, i.e. more priming effects than level priming. Both predictions were confirmed.

Contingencies and thus the CE were related to priming. The PECOG study showed that RTs in adults were higher after switching in the 80% contingency compared to 50%, but level- and identity-priming did not differ. This indicated that no further benefit was gained by having even more trials with priming in the 80% than the 50% contingency in that study. This was not replicated in the current sample; instead, RTs were lower in the 50% condition in all three priming conditions compared to 80% (no significant interaction of (Priming x Contingency). This reflected the CE and showed that RTs reduce more, the more primed trials were in a block (as also shown by Katagiri et al., 2013; Keita, Guy, Berthiaume, Mottron, & Bertone, 2014; Wiggs & Martin, 1998).

No predictions were made regarding the relationship between stimulus durations times and PESC. Peel, Sperandio, Laycock, and Chouinard (2018) reported that priming was unsuccessful when prime stimuli (duration 48ms) were masked and did not reach conscious awareness in participants. At durations of 150ms in the current study, conscious awareness of the stimuli was very likely, even in MASK. Nevertheless, it was probable that PESC would be lower in MASK compared to SHORT and LONG, The data did not support this, as PESC did not differ between duration conditions.

In sum, the analyses showed that children had more difficulties switching between processing levels compared to adults. They also benefitted more from priming in terms of accuracy on the global level, whereas the local level was not affected in LONG.

### 8.1.5 Q5: The relationship between LGP and autistic traits in TD

In this section, two analyses were performed to examine the relationship between LGP and autistic traits: a correlation approach and an extreme group approach (EGA).

#### 8.1.5.1 Results

*Summary of results*: Both, correlation and EGA showed that in the older age group, higher AQ scores were associated with more global bias (RT) in the standard condition. The EGA further showed that biases were overall more pronounced in the higher AQ group.

Descriptive Tables can be found in Appendix G.1.1.3(Table *G.13* and Table *G.14*). Tables with the inferential statistics of the EGA can be found in Appendix G.2.1. (Table *G.36*).

#### 8.1.5.1.1 *Correlation approach*

Total scores of the participants on the AQ ($AQ_{total}$) were correlated with the Bias Indicators (BI). The correlations were calculated for the whole sample and separately for each age group.

The Pearson correlation between the $BI_{RT\text{-}SHORT}$ and $AQ_{total}$ was not significant ($r$ = -.162, $p$ = .188). However, the non-parametric Spearman's rho revealed a significant weak negative correlation *(rho* = -.273, $p$ = .024, see Table 8.6): the higher the total AQ score, the lower the $BI_{RT}$, therefore the more global bias the participant showed. This relationship was mainly carried by the adult group (*rho* = -.589, $p$ = .002) and the adolescent group (*rho* = -413, $p$ =.0499), but not the child group (*rho* = .101, $p$ = .662). See Figure 8.9 for a depiction of the relationship between the $BI_{RT\text{-}SHORT}$ and AQ in each age group. There were no significant correlations between the AQ and the $BI_{RT}$ in the LONG or MASK conditions; however, the $BI_{ACC}$ had significant correlations in the adolescents in SHORT and MASK (see Table 8.6).

Table 8.6

*Results from the correlation analysis between BI and AQ-Scores in each TD age group and overall (VISTA study)*

| | duration | | child | adolescent | adult | overall |
|---|---|---|---|---|---|---|
| $BI_{RT}$ | G20l80 | *r* | | | | |
| | | *rho* | | | .414* | |
| | short | *r* | | | -.591** | |
| | | *rho* | | -.413* | -.589** | -.273* |
| | G80l20 | *r* | | | | |
| | | *rho* | | | | |
| | long | *r* | | | | |
| | | *rho* | | | | |
| | mask | *r* | | | | |
| | | *rho* | | | | |
| $BI_{ACC}$ | G20l80 | *r* | | | | |
| | | *rho* | | | | |
| | short | *r* | | | | |
| | | *rho* | | -.434* | | |
| | G80l20 | *r* | | | | |
| | | *rho* | | | | |
| | long | *r* | | .576* | | |
| | | *rho* | | .591* | | |
| | mask | *r* | | -.602** | | |
| | | *rho* | | -.540** | | |

Note. Only significant correlations are reported. *: $p < .05$; **: $p < .01$

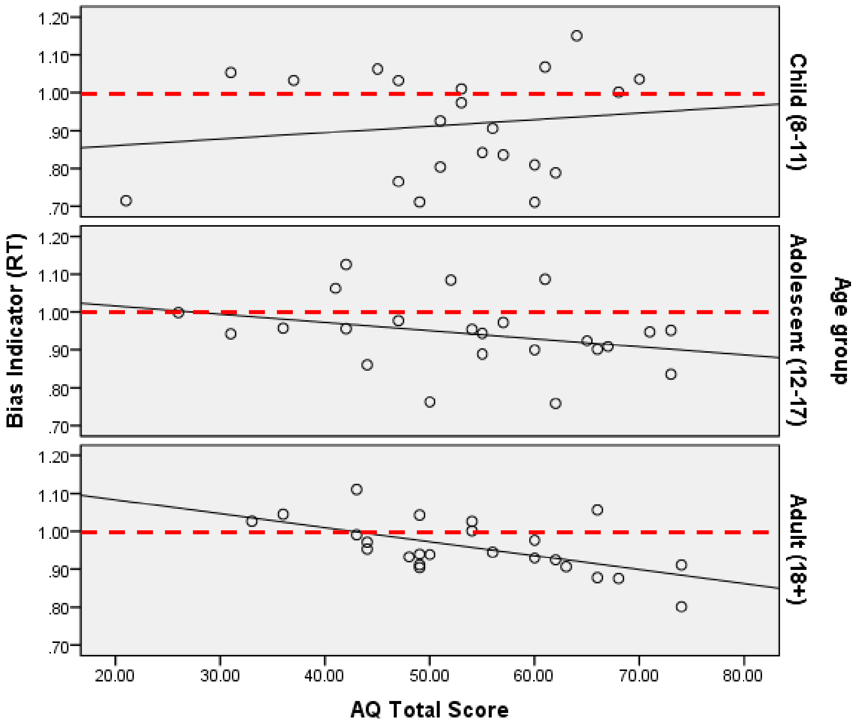



*Figure 8.9.* The relationship between the AQ Total Score and Bias Indicator $BI_{RT}$ (block: G50L50/SHORT) in each age group.
Horizontal lines (- - -) indicate BI = 1: no bias. BI < 1: global bias. BI > 1: local bias. Explained variance $R^2$ in per group: Child = 2.2%, Adolescent = 9.6%, Adult = 34.9%.

### *8.1.5.1.2 Extreme groups approach (EGA,* Table G.36*)*

In the Extreme Group Approach (EGA), participants with high and low $AQ_{total}$ scores were compared on the BIs. The sample was split into a younger (child) and older group (adolescents and adults), as previous reported analyses showed similar results in adolescents and adults in contrast to the child group. Extreme groups regarding the AQ were selected based on the first and third tertile of the AQ total scores of the age groups (similar to Grinter et al., 2009; see Preacher, Rucker, MacCallum, & Nicewander, 2005, for a discussion of the EGA). In the younger participants, the low AQ group included participants with scores up to 49 and the higher AQ group scores over 59 ($n$ = 7 in either group). In the older participants, the cut-offs were 49 (low AQ) and 60 (high AQ, $n$ = 15 in either group). Following, the extreme groups were included in two 5x2x2 ANOVAs with the factors block (G20L80, G50L50, G80L20, LONG, MASK), age group (younger, older) and AQ group (lower, higher), once for the $BI_{RT}$, once for $BI_{ACC}$. Of particular interest were the main factor AQ group and its interactions.

The 5x2x2 ANOVA with the DV $BI_{RT}$ revealed a significant interaction of Block x AQ Group ($p < .001$). As can be seen in Figure 8.10a, in the lower group only the G80L20 condition had a significant bias ($BI \neq 1$), whereas all blocks in the higher AQ group had a significant bias. Further, in the lower AQ group, the CE (i.e. the flexibility of the bias) was less pronounced: Compared to the lower AQ group, the higher AQ group had significantly more local bias in G80L20, and more global bias in G50L50 and MASK (all $p < .05$).

The ANOVA with the DV $BI_{ACC}$ did not show any effects of AQ group.

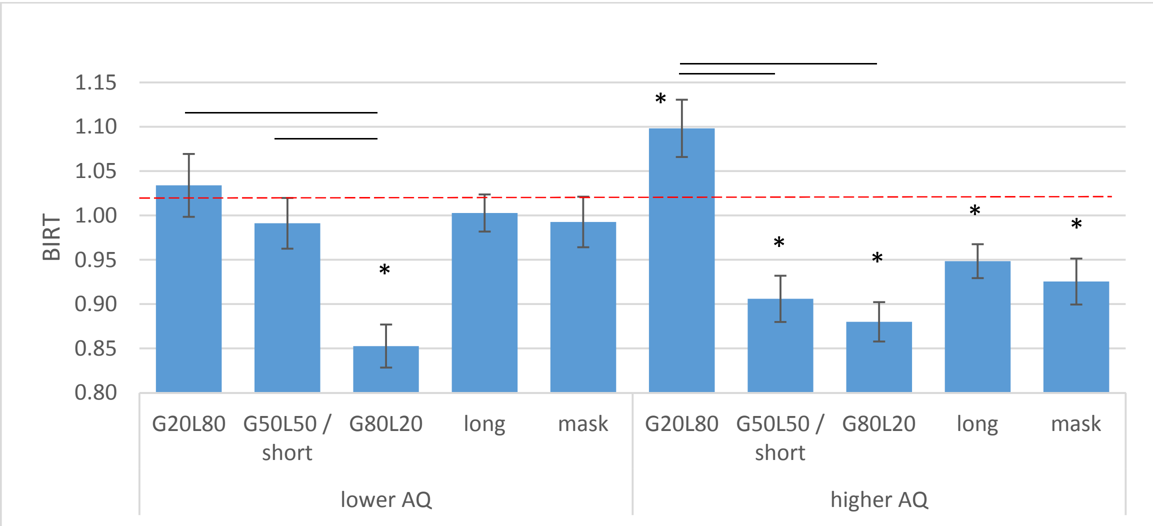



*Figure 8.10.* $BI_{RT}$ in the experimental blocks in the lower and higher AQ groups (over all ages).
* indicate significant bias ($BI \neq 1$) with $p < .05$. — indicate significant differences between blocks with variable contingencies with $p < .05$, thus the CE.

### 8.1.5.2 Summary and Discussion

A non-parametric correlation analysis showed that in the older participants there was a negative relationship between the $BI_{RT}$ and AQ Score in the standard G50L50 block, whereas BI and AQ were independent of each other in younger participants. This was the opposite of what was expected based on previous research which showed that more autistic traits were associated with increased local bias or reduced global bias (see meta-analysis by Cribb et al., 2016). The EGA further showed that biases (and the CE) were more pronounced in the higher AQ group.

Huizinga et al (2010) suggested that children show a global bias and that local processing, as well as level switching, do not reach a sophisticated level until later in life (cf. also Niaz, 1987). The current developmental data has shown that descriptively, older participants had less global bias compared to younger ones. It could be that mature processing is not as easily reached in individuals with more autistic traits; thus, they show more child-like processing (here: more global bias), while in those with lower AQ scores, the bias reduces with age (cf. Figure 8.11). One might, hypothesise that individuals with ASD (child age and older) who per definition have higher AQ scores would perform similar to TD individuals with higher AQ scores and therefore in a similar manner to TD children. Thus, they would show a delay in development with more pronounced biases. This will be explored in Section 8.2.

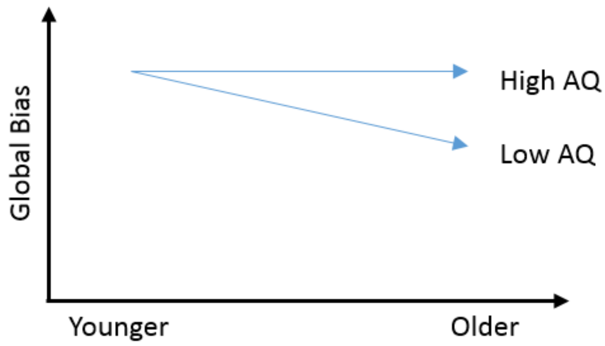



*Figure 8.11.* The suggested relationship between age and prevalence of autistic traits.
While those individuals with high AQ scores have a stable global bias, the bias decreases with age in those with low AQ scores.

### 8.1.6 Summary: Local and global processing in TD

This study was conducted in order to examine aspects of LGP in development, including processing biases, their flexibility, the ability to switch between processing levels between trials, the influence of stimulus presentation times, and of autistic traits. 68 participants aged 7 to 52 completed a range of hierarchical figures task and the AQ questionnaire. The analyses of the data supported some, but not all predictions.

The main findings were that overall, perception biases were not affected much by the manipulations. Adolescents generally performed similar to adults, while children showed higher RTs and lower accuracy. Descriptively, children also had more global bias in RTs in the standard condition (G50L50) than the older age groups. All age groups showed a global advantage which was influenced by contingencies with higher global bias in G80L20 and less global bias in G20L80, showing flexibility of the bias/shifting of attention when analysed on a block basis. The youngest group seemed to have slightly reduced flexibility, as they did not have a local bias in G20L80 regarding RTs.

The ability to switch the attended level on a trial-by-trial basis improved with age so that RTs and accuracy were not as much affected by PESC in adolescents and adults as they were in children. This was further evidence for a reduced ability to shift perception biases in children.

Stimulus durations did not affect processing biases in the older age groups (in contrast to the results in PECOG). However, in children's accuracy data there was a trend towards a negative impact of masking on local processing. Further, long presentation times were accompanied with a tendency towards a local bias in children. It was hypothesised a) that this could reflect the epigenetic development of LGP with local processing maturing only after global processing (cf. Huizinga 2010), and b) that some children might (still) have a local processing preference which becomes apparent in certain conditions (here: long presentation times), although their more automatic performance (in shorter durations) reflects the GPE (cf. Poirel, Mellet, et al., 2008; Wang et al., 2007).

The examination of the influence of autistic traits revealed that in older participants more autistic traits were associated with more global bias, which could be seen as more child-like given that TD children tended to have more global bias than older groups. Potentially, participants with a diagnosis of ASD would also perform more like younger TD participants, indicating a developmental delay in the clinical group. This and other aspects were examined in the next section.

## 8.2 Local and global visual processing in Autism Spectrum Disorders (ASD)

### 8.2.1 Introduction

Section 8.1 presented data from a sample of typically developing (TD) participants and aimed to determine normative trajectories in various aspects of LGP. Now, findings will be reported from a cross-sectional sample of 50 individuals with ASD who completed the same battery of tasks. The ASD data will be analysed together with the data from an age-matched TD sample (a sub-sample from the sample in Section 8.1) in order to compare both groups.

There is an ongoing debate in the research community whether or not individuals with ASD have normal, impaired or enhanced LGP (see also Chapter 3). For example, the weak central coherence Theory (Frith, 1989) claimed in its original version that global processing was reduced in ASD as those individuals would process scenes or stimuli in a more piece-meal approach and not show as much influence from the global picture as TD individuals did. Later on, it was proposed that global processing in ASD was intact, but local processing was enhanced (Happe & Frith, 2006) which was also in line with other theories like the enhanced perceptual functioning theory (EPF, Mottron & Burack, 2001). However, more recent work (Booth & Happé, 2016) concluded again that global integration is in fact reduced in ASD.

A different approach to explaining processing in ASD is the executive dysfunction theory which states that executive functions (EF) are impaired in this clinical group (Ozonoff et al., 1991). Aspects of EF include flexibility, attention shifting, working memory, planning, and response inhibition which have all been previously been reported as impaired in ASD (for reviews and meta-analyses see Craig et al., 2016; Demetriou et al., 2017; Geurts et al., 2014; Hill, 2004; Kercood et al., 2014; O'Hearn et al., 2008). It has been proposed that central coherence, i.e. processing information in context for global meaning, could be seen as a facet of EF and that impaired central coherence might be due to a reduced ability to shift between processing levels (Happe & Frith, 2006).

To date, no theory about LGP in ASD can explain all the findings that the research community compiled. Accordingly, even conclusions from meta-analyses (Muth et al., 2014) and reviews (Happe

& Booth, 2008) disagree on whether or not LGP is intact, reduced or enhanced. One reason for these discrepancies might be varying definitions of what LGP is and how it can be assessed (Chamberlain et al., 2017; Milne & Szczerbinski, 2009; Van der Hallen et al., 2015). Further, task characteristics like stimulus sizes or exposure times (e.g. Wang et al., 2007, cf. Chapter 7), attentional demand (Plaisted et al., 1999; Pletzer et al., 2017), or wording (Scott et al., submitted, as cited in Happe & Frith, 2006) could play a role in the outcome of LGP studies (see also Sections 2.6 and 3.4). Moreover, it was suggested that enhanced local processing and/or reduced global processing is not universal to ASD; thus a percentage of individuals might show normal LGP (Booth, 2006; Heaton, Hudry, et al., 2008; O'Reilly et al., 2013; Pellicano, 2012). Lastly, developmental aspects can play a role, although even within age groups reports are very mixed (see Section 3.4.1). Direct comparisons of different age groups from childhood to adulthood with the same experimental tasks are rare. An exception is, for example, Scherf et al.'s (2008) study in which the authors found that individuals with ASD showed enhanced local processing in all age groups, while global processing did not reach the same standard in ASD as in TD adults. Development of LGP has been suggested to be delayed in ASD (in language: Chahboun et al., 2016; in vision: Van Eylen et al., 2018). However, findings regarding age influences in LGP are inconclusive and Muth et al. (2014) established in their meta-analysis that age differences could not explain the heterogeneous results regarding LGP across studies.

As apparent, many issues surrounding LGP in ASD are still not satisfactorily answered. The current study sought to develop a better understanding of LGP in ASD on its own as well as in comparison to TD. 50 participants aged 8 to 54 with a diagnosis of ASD completed the same experiments with hierarchical figures as the TD sample in Section 8.1 in order to address the following questions:

- *Question 1: What is the developmental trajectory of processing biases in ASD?*

  Based on the majority of research findings (see Chapter 3), it could be expected that participants with ASD exhibit a local bias in the hierarchical figures task. However, the results of the cross-sectional TD sample (Section 8.1) revealed a slight tendency towards more global bias in children compared to older participants, as well as more global bias in older participants with higher amounts of autistic traits (AQ). Thus, if individuals with ASD have a developmental delay regarding LGP (Chahboun et al., 2016; Van Eylen et al., 2018) and individuals with more autistic traits show more global bias, it is likely to find a global bias in ASD in this particular task, potentially even more than in TD.

- *Question 2: Do stimulus presentation times influence biases in ASD differently than in TD?*

  In TD (Section 8.1) children had a more pronounced global bias $BI_{RT}$ in the SHORT and MASK conditions compared to LONG. They also showed a tendency for more global bias regarding accuracy when processing was interrupted by the mask. The same might be found for participants with ASD assuming they showed a developmental delay. Based on our previous results it would be expected that older groups, especially adults are less affected by stimulus duration.

- *Question 3: Can participants with ASD of all age groups flexibly adjust their biases in a comparable manner to TD?*

  EFs including cognitive flexibility and adaptive behaviour have been reported to be reduced in ASD (e.g. meta-analysis by Demetriou et al., 2017) ; therefore, it could be expected that this would be reflected in a weaker CE and a more rigid bias across all contingency conditions. On the other hand, Iarocci et al. (2006) and Hayward et al. (2012) demonstrated intact bias shifting in ASD. The ASD children in Iacorri et al.'s study even showed more sensitivity to the bias manipulation than TD children. However, given the result in Section 8.1 that TD children had a less pronounced CE and Huizinga et al.'s (2010) claim that switch ability develops with age, this reduced CE would also be expected for the current ASD children and potentially also the older age groups with ASD.

- *Question 4: Do switch costs in ASD differ from TD, are they dependent on age, level, stimulus duration or contingency and are there different effects of level- and identity-priming?*

  Reduced EF in ASD could not only reduce the CE but also impair switch ability on a trial-by-trial basis leading to higher PESC in ASD (Soriano, Ibáñez-Molina, Paredes, & Macizo, 2018). Whether or not stimulus duration or level-and identity priming lead to different results remained open. However, as identity priming has been shown to benefit RTs more than level-priming in

TD (Section 8.1), this is likely to be the case also for ASD. To our knowledge, this has not yet been examined by other researchers.

- *Question 5: Is there a relationship between the amount autistic traits and processing biases in ASD and across both sample groups?*

  In Section 8.1, we found that in TD higher AQ scores were associated with more global bias in adolescents and especially in adults, although the opposite had been predicted. Potentially, participants with ASD would also show a global bias and the extent would vary with the amount of autistic traits reflecting the same negative relationship between the BI and AQ-scores.

To summarise, it would be predicted that participants with ASD exhibit a developmental delay which would be apparent by their performance being more like that from TD children with higher RTs, lower accuracy, more global bias, less switch ability and bias flexibility compared to age-matched TD.

### 8.2.2 Method

#### 8.2.2.1 Subjects

50 participants with a diagnosis of ASD aged 8 to 54 ($M$ = 22.54, $SD$ = 14.84) took part in these experiments (10 females, 40 males). The average VP score was 62.8 (11.0), NVP score 52.18 (8.4), FSIQ2 113.2 (14.2) and AQ 97.6 (19.5). Please see Table 8.7 for a more detailed sample description.

The individually age-matched TD sample (AmTD, see Table 8.7) consisted of a selection of 45 participants from the original larger TD sample (as described in Section 8.1.2.1). Overall, AmTD and ASD did not differ relative to gender, $\chi^2$ (1) = 3.679, $p$ = .055, or age, $t$(90.4) = 1.342, $p$ = .183. The ASD age groups had significantly higher AQ scores than the AmTD age groups (all $p$ < .001). The sample groups did not differ neither in adolescent nor adult groups regarding verbal performance (adolescents: $t$(29.3) = .748, $p$ = .461; adults: $t$(29.7) = 5.188, $p$ = .103), nonverbal performance (adolescents: $t$(32) = 1.703, $p$ = .098; adults: t(34) = 1.287, $p$ = .207) or full scale IQ (adolescents: $t$(32) = 1.278, $p$ = .210; adults: $t$(34) = 1.961, $p$ = .058). However, children differed in the IQ measures with AmTD having higher verbal performance scores than ASD, $t$(17,6) = 2.935, $p$ = .009, higher nonverbal performance scores,

$t(23) = 3.399$, $p = .002$, and higher FSIQ, $t(23) = 3.604$, $p = .001$. The child groups also differed significantly in the gender ratio, $\chi2$ (1) = 4.396, $p = .036$.

Table 8.7

*Sample characteristics of the ASD and AmTD sample*

| Group | N | Age *M(SD),* [range] | Gender (f:m) | VP | NVP | FSIQ2 | AQ |
|---|---|---|---|---|---|---|---|
| ASD | | | | | | | |
| Children | 12 | 9.5 (0.9) [8.1-10.8] | 0:12 | 64.5 (6.4) [48-80] | 50.2 (6.4) [39-62] | 107.3 (17.8) [77-135] | 107.3 (17.8) [77-135] |
| Adolescents | 18 | 14.8 (1.9) [12.3-17.7] | 3:15 | 63.8 (10.7) [42-80] | 49.4 (10.5) [29-62] | 112.1 (16.1) [78-136] | 86.8 (16.7) [59-128] |
| Adults | 20 | 37.3 (13.2) [18.8-54.8] | 7:13 | 61.0 (11.9) [38-76] | 55.7 (6.6) [37-65] | 101.4 (18.9) [68-138] | 101.4 (18.9) [68-138] |
| AmTD | | | | | | | |
| Children | 13 | 9.7 (1.1) [8.3-11.1] | 4:9 | 74.4 (6.0) [64-80] | 59.6 (7.4) [38-70] | 131.2 (11.9) [101-147] | 52.8 (11.9) [21-70] |
| Adolescents | 16 | 14.7 (1.8) [12.7-17.6] | 6:10 | 66.1 (6.9) [42-79] | 53.5 (6.6) [42-62] | 118.1 (9.8) [103-138] | 50.7 (12.5) [26-71] |
| Adults | 16 | 30.6 (11.3) [18.2-52.8] | 7:9 | 66.2 (6.2) [53-75] | 58.5 (6.6) [47-69] | 122.1 (9.3) [108-137] | 54.8 (12.9) [33-74] |

*Note.* AmTD: Age-matched TD. For age, VP, NVP, FSIQ and AQ means, standard deviation and range [min-max] are given. For VP and NVP given as standard scores ($M = 50$, $SD = 10$). The AQ was scaled on 1-3 for all age groups for comparability. Original scaling of ASD adolescent and adult samples gave values for adolescents of *M(SD)* = 30.1(6.7), range [19, 43] and for adults *M(SD)* = 36.3(7.6), range [23, 49]. AQ cut-off scores: children = 76, adolescents = 30, adults = 32. No ASD children, 8 adolescents and 5 adults scored below the recommended cut-off scores. No AmTD scored above the AQ cut-off scores.

#### 8.2.2.2 Procedure

The procedure was the same as described in Section 8.1.2.2.

#### 8.2.2.3 Analysis

The analyses were performed equivalently to the analyses in TD (as described in Section 8.1.2.3, Table 8.2, Table 8.3) but with the additional between-subjects factor sample (AmTD vs ASD).

The results will be presented in separate sections for each experimental task/research question. Descriptive tables and ANOVA statistics can be found in Appendices G.1.2 and G.2.

No speed-accuracy trade-off was found in the ASD participants ($p > .05$).

### 8.2.3 Q1&3: Perception Bias and its Flexibility in ASD compared to TD

This section examined what processing bias individuals with ASD have as well as how flexibly it could be overcome (CE), in particular in comparison to TD.

#### 8.2.3.1 Results

*Summary of results*: The ASD group had a global bias ($BI_{RT}$) in RTs like in TD, while in accuracy there was mostly no significant bias and no differences between sample groups. Across both sample groups, children responded slower and less accurate than the older age groups. Both sample groups showed a CE in RTs. However, in accuracy, participants with ASD as a group, as well as children (TD and ASD) showed no CE for the local level.

Descriptive Tables for the ASD group can be found in Appendix G.1.2.1 (for RTs Table *G.15*, accuracy Table *G.16*) and G.1.1.3 (for BIs, Table *G.25*). Tables with the inferential statistics can be found in Appendix G.2.1. (Table G.28 and Table G.29).

##### *8.2.3.1.1 Reaction Times (*Table G.28*)*

A 2x3x2x2 repeated-measures ANOVA with the factors level, contingency, age group and sample group revealed no significant effect of sample group or its interaction with other factors ($p > .05$). Significant main effects were level ($p < .001$; faster RT to global ($M$ = 721ms) than local targets ($M$ = 765)), contingency ($p < .001$), and age group ($p < .001$), which was equivalent to the TD analysis. Pairwise comparisons of the CE revealed that across age groups and samples, there was no significant difference between the 20% ($M$ = 765ms) and 50% condition ($M$ = 769ms, $p$ = 1), but between the 50% and 80% condition ($M$ = 683ms, $p < .001$). Children ($M$ = 876ms) responded slower than adolescents ($M$ = 678ms, $p < .001$) and adults ($M$ = 663ms, $p < .001$) who did not differ ($p$ = .1).

##### *8.2.3.1.2 Bias Indicator ($BI_{RT}$,* Table G.29*)*

A 3x3x2 repeated measures ANOVA (Block x Age Group x Sample) and the DV $BI_{RT}$ revealed that block had a significant effect on the $BI_{RT}$ ($p < .001$), but no other significant main effects or interactions.

Equivalent to the TD analysis, the CE was examined in more detail. In ASD, as in TD, there was a significant reduction of the BI from the G20L80 block over G50L50 to the G80L20 block when testing the whole sample ($p < .001$). When the CE was examined in the ASD age groups, the CE was not significant in children (see Table 8.8). Further, the $BI_{RT}$ was significantly different from 1 (no bias) in no condition in ASD children (although G80L20 was $p = .061$), only the G80L20 condition in ASD adolescents (but the others were nearly significant, $p = .053$ and $p = .051$), and the G50L50 and G80L20 condition in ASD adults (cf. Figure 8.12).

Table 8.8

*ASD Results of the pairwise comparisons testing differences in the Bias Indicators BIRT between blocks with different contingencies (VISTA study)*

| | | G20L80 vs G50L50 | | | G50L50 vs G80L20 | | |
|---|---|---|---|---|---|---|---|
| | | *t* | *p* | *d* | *t* | *p* | *d* |
| child | *df* = 10 | -1.497 | .165 | -.451 | -1.430 | .183 | -.431 |
| adolescent | *df* = 17 | -2.769 | .013 | -.653 | -3.304 | .004 | -.779 |
| adult | *df* = 18 | -3.516 | .002 | -.807 | -3.438 | .003 | -.789 |

*Note: d*: effect size. Adjusted alpha level $\alpha = .025$.

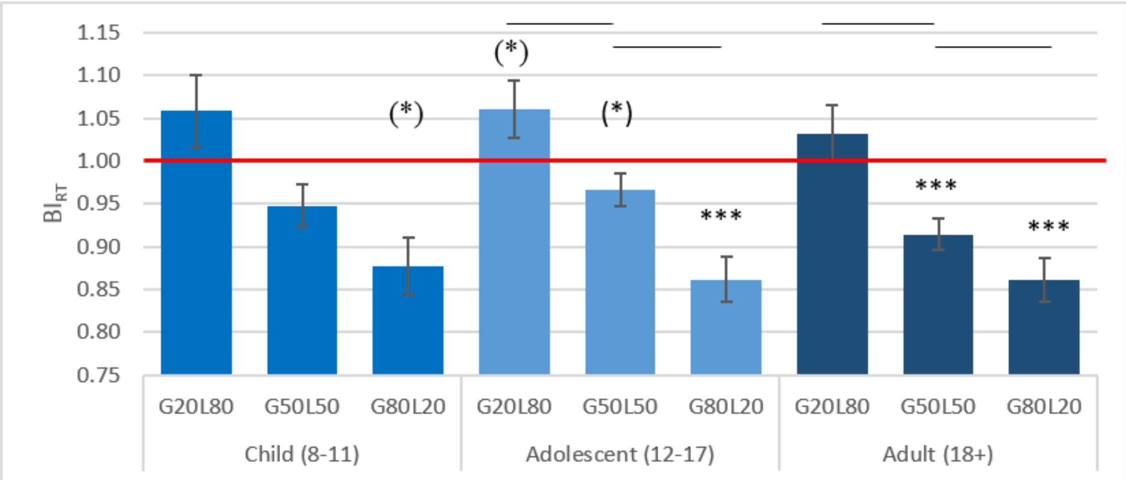



*Figure 8.12.* Bias Indicator $BI_{RT}$ per ASD age group and block.
* indicate *p*-values in one-sample tests against test value 1. (*): $p < .1$, *: $p < .05$, **: $p < .01$, ***: $p < .001$.
—indicated significant pairwise comparisons between blocks.

#### 8.2.3.1.3 *Accuracy (*Table G.28*)*

A 2x3x2x2 repeated-measures ANOVA with the factors level, contingency age group and sample revealed the significant interaction Level x Contingency x Sample ($p = .017$). While the Level x Contingency interaction was nonsignificant in TD ($p = .703$), it was significant in ASD ($p = .004$).

When exploring the interaction in ASD, post-hoc tests showed that for global targets there was a consistent CE (ACC in 20% < 50% < 80%, all $p < .013$), whereas in local targets no CE was found (all comparisons $p > .05$, see Figure 8.13a). No other sample specific effects were found. The interaction Level x Contingency x Age Group was significant ($p = .012$): In children, a CE was found in global trials but less in local trials (cf. Figure 8.13b, for effect in adolescents and adults please refer to the figure).

The ANOVA further showed that the main effect of contingency was significant ($p < .001$): 20% contingency had the lowest accuracy ($M = 93.1\%$) followed by 50% ($M = 95.7\%$, $p < .001$) and 80% ($M = 95.8\%$, $p < .001$) whereas the latter two did not differ ($p = 1$). Lastly, age group was significant ($p = .003$): children had the lowest accuracy with 91.2% followed by adolescents ($M = 96.3\%$, $p = .016$) and then by adults ($M = 97.1\%$, $p = .014$).

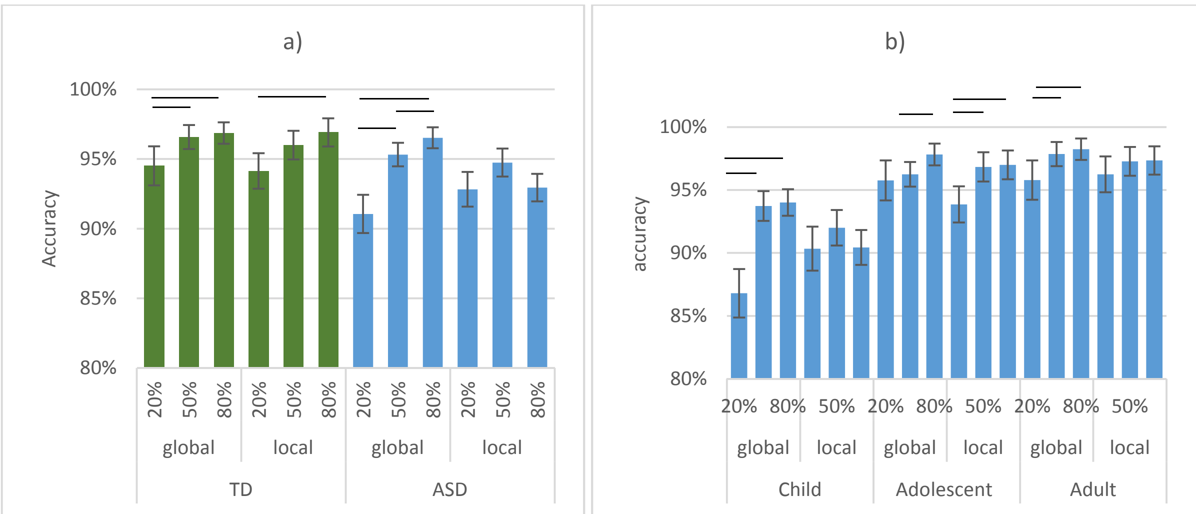



*Figure 8.13*. Accuracy data of participants in different contingencies.
a) in AmTD and ASD (age groups together), b) in children, adolescents and adults (AmTD and ASD together). Significant comparisons are indicated with ─ ($p < .05$).

#### 8.2.3.1.4 *Bias Indicator ($BI_{ACC}$, Table G.29)*

A 3x3x2 repeated measures ANOVA with the factors block, age group and sample, and the DV $BI_{ACC}$ revealed that only block was a significant main effect ($p = .001$). No age or sample specific effects were found, although the interaction of Block x Age Group was not far from significant ($p = .064$). As can be seen in Figure 8.14, the child groups exhibited a slightly more pronounced local bias in the G20L80 block than the other age group.

Pairwise comparisons for the factor block showed that over both samples, the CE was significant with a reduction of the $BI_{ACC}$ from the G20L80 ($M$ = 1.03) to the G50L50 block ($M$ = 99.4, $p$ = .008), and from G50L50 to G80L20 ($M$ = 96.7, $p$ = .017).

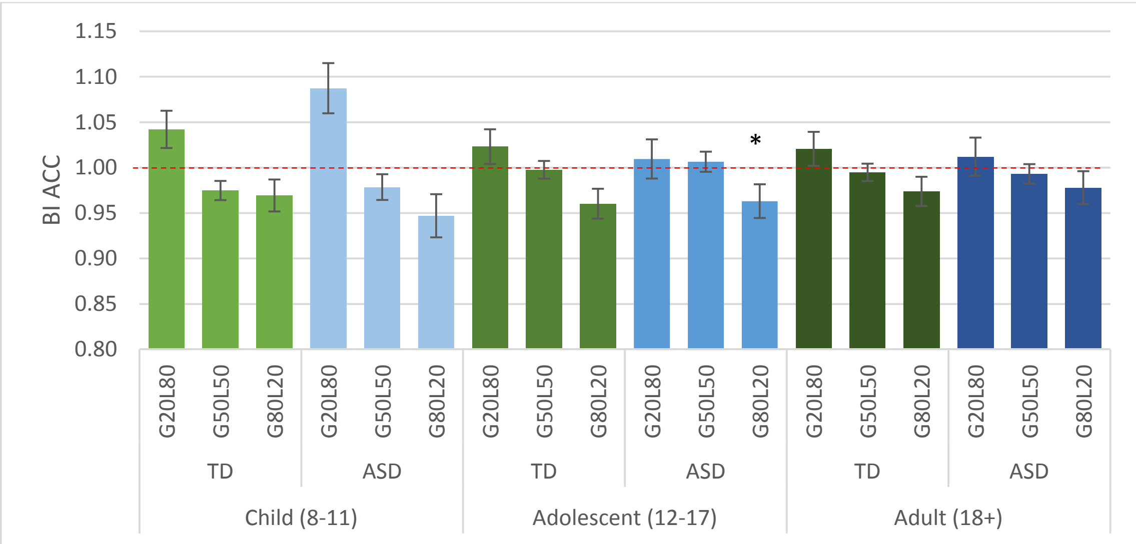



*Figure 8.14.* Bias Indicator $BI_{ACC}$ for AmTD and ASD in each contingency block.
*indicates a significant bias with BI ≠ 1.

When the $BI_{ACC}$ was examined separately in the age groups in ASD (for BI ≠ 1), it was only significantly different from 1 in adolescents in the G80L20 block (global bias), $t(17) = -2.197$, $p = .042$, $d = .518$, but no other conditions/age groups ($p > .05$), indicating no significant bias in the majority of the accuracy data.

#### 8.2.3.2 Summary and Discussion

##### *8.2.3.2.1 What is the developmental trajectory of processing biases in ASD and how does it compare to TD?*

Despite the common assumption that individuals with ASD have a local processing bias or advantage (e.g. Bölte et al., 2007; Ropar & Mitchell, 2001), this was not confirmed with the current tasks; instead, a global processing bias was found. Given the findings from the TD sample in Section 8.1 this was not that surprising: First, TD children were found to exhibit a global bias in the standard G50L50 condition (see Section 8.1.3.1, although a common assumption/finding is that children have a local bias or processing advantage). Second, older TD participants with higher amounts of autistic traits showed more global bias than those with less autistic traits. The results for the ASD group are therefore in line with these findings. One might argue that the task characteristics led to a global processing advantage; thus, the reason might be not an intrinsic participant processing bias but, an one that was extrinsically imposed by the implemented stimuli. However, this seems implausible, as the same stimulus set elicited a local processing advantage in the G20L80 block. If the stimuli per se were compromising local processing, a local bias would rather not have been found in this block.

The global processing bias was comparable in TD and ASD participants. This is in line with the findings from other researchers who compared children (Iarocci et al., 2006; Plaisted et al., 1999), adolescents (Mottron et al., 2003) and adults (Hayward et al., 2012) with and without ASD. Others found reduced global processing in Autism but not in Asperger's Syndrome (AS, Rinehart et al., 2000). Potentially, if the current study differentiated between subtypes of ASD, differences between those groups would have been found. However, as the diagnoses of Autism and AS have been replaced by the overarching diagnosis of ASD in the DSM-5 in 2013 and some participants received a diagnosis only after this date, a distinction into subtypes would have been difficult.

There was not much variation in the bias between age groups which is consistent with a recent meta-analysis including 56 studies which revealed that age was not a moderator when examining LGP in TD and ASD (Van der Hallen et al., 2015). Scherf et al. (2008), however, found that in TD a global advantage developed with age, but that there was no relationship between age and global advantage in ASD. Scherf et al. used a different indicator for the global advantage to the current BI (see formulas in the caption of Figure 8.15). However, Gerlach and Krumborg (2014) demonstrated in a comparative analysis that different bias indicators can lead to different results and therefore different conclusions. Nevertheless, even when a global advantage score was calculated from the current data equivalently to Scherf et al., results remained the same: no significant relationship between age and bias was found (see Figure 8.15).

A)

Aston University

Illustration removed for copyright restrictions

B)

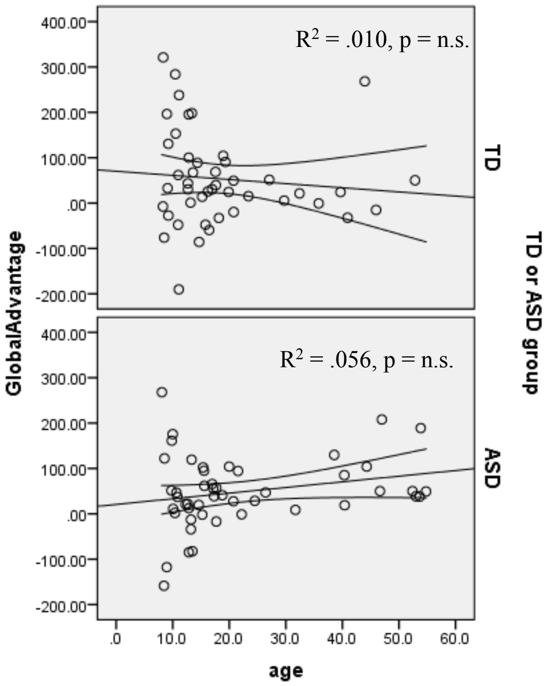



*Figure 8.15.* Comparison of the relationship between age and global advantage in (A) Scherf et al. (2008, p. 133) and (B) the current study.
Global advantage is shown as a function of age with 95% confidence intervals. A) Global advantage = [(local inconsistent–local consistent) – (global inconsistent–global consistent)]. B) Global advantage = local – global. Explained variance in (B) for TD: $R^2$ = .010 (n.s.); for ASD $R^2$ = .056 (n.s.).

It could be argued that the task used was unsuited to discover age effects in the samples. The analysis of the accuracy data, for example, showed no overall perception bias at all (neither in TD nor ASD). Potentially, a more difficult task would have been better able to elicit age differences in the perception bias; however, despite not finding age differences in the biases, differences were found in the RT and accuracy data: both, TD and ASD children responded slower and less accurate than the older groups. Thus, the tasks allowed for a certain amount of variation between participants which could have also been reflected in variability in the bias.

##### *8.2.3.2.2 Can participants with ASD of all age groups flexibly adjust their biases and how do they compared to TD?*

Based on the findings that EFs including cognitive flexibility are reduced in ASD, it was expected that the CE might be reduced in ASD. However, this was not confirmed. Equivalently to Hayward et al (2012) and Iarocci et al. (2006), participants with ASD were able to shift their global bias (regarding

RTs) to a more local bias in G20L80 and a stronger global bias in G80L20. Intact cognitive flexibility in ASD was also reported by Poljac et al. (2010).

Nevertheless, in TD children and particularly ASD children, the CE was less pronounced on the group level: The change in bias was only significant in TD children from G20L80 to G50L50, but not to G80L20. In ASD children, the differences between blocks were not significant at all. Thus, children showed slightly reduced flexibility. The results are in contrast to Iarocci et al. (2006) who demonstrated that ASD children were even more sensitive than TD regarding implicit bias manipulations and were better able to tune into the implicit demands of the task in order to overcome their bias. Their sample consisted of young children aged 7-8 years and was thus on average 1.5 years younger than the current child sample. The stimuli used in their and the current study were very similar, except that Iarocci at al.'s were filled in on the local level, smaller (ca. half the size), and the task was arranged differently for a visual search task. Potentially, the slightly younger age, different tasks and stimuli are responsible for the dissimilar results.

The analysis of TD's and ASD's accuracy data in a combined ANOVA produced interesting results: First, there was an interaction between level and age group: while there was a significant increase in accuracy for children in global trials, this was not the case for local trials (Figure 8.13 on page 171). The other age groups either performed very close to ceiling or showed a significant difference between contingencies in both local and global trials. Thus, in the total child group, a similar effect of an invariability of accuracy to local trials was found like in the switch costs analysis in Section 8.1.3.1.1 on page 154: there, accuracy in local trials was unaffected by priming in TD children, whilst there were significant PESC in global trials (in the block LONG). Second, there was an interaction between level and sample group: In TD, a CE was found for local and global trials, whereas in ASD the higher accuracy with increased contingencies were only found for global trials. A more detailed analysis of the descriptive accuracy data showed that in all ASD age groups, accuracy to local targets increased from the 20% to 50% contingency, but then dropped again in the 80% contingency. It appears that in children and in ASD, contingencies benefited participants successfully for global processing but only to a certain degree in local trials. Interestingly, Iarocci et al. (2006) found that the sensitivity to the CE in ASD was comparable on the local and global level, while in the nonverbal mental age-matched TD group the CE was strong for global and weak/non-existent for local trials. Unfortunately, Iarocci et al. do not explain the missing effect in local trials. Potentially, the global bias in our task was so stable in ASD that although they managed to shift their bias in G20L80 to a more local bias, this was accompanied with bigger cognitive load, resulting in a generally less accurate performance in that block.

Children (in TD but more in ASD) showed a more pronounced tendency towards a local bias $BI_{ACC}$ in G20L80 compared to the older age groups. Possibly, once the children tuned into a certain processing level, it was more difficult for them to elude it again. However, this has to be interpreted with caution, as the interaction Contingency x Age Group was not significant ($p$ = .064). Cowan, Morey, AuBuchon, Zwilling, and Gilchrist (2010) demonstrated in a working memory task with 4 different attention conditions (20%, 50%, 80%, 100%) that children were able to allocate attention in a similar manner as adults. However, the efficiency in attention allocation reduced in children when cognitive load increased. Potentially, this applies to the current study, too: Although children were able to allocate attention to a specific level depending on the contingency, this was less efficient than in adults. This increased cognitive load or effort could potentially also explain the reduced CE in RT for children and ASD participants. Fittingly, Richard and Lajiness-O'Neill (2015) found comparable shifting abilities between TD and ASD children and concluded that although both groups are able to shift attention from one level to the other, the underlying processes differ so that in ASD it is a more effortful, higher order task, whereas it is a more basic, effortless task in TD. According to Kaldy, Giserman, Carter, and Blaser (2016) individuals with ASD have overintense attentional focus, which the authors were able to demonstrate in a technique called in pupillometry but not other eye-tracking or behavioural data. Potentially, such an increased underlying attentional focus could make level switching more strenuous for ASD participants.

In sum, children (TD and ASD) showed a less pronounced CE compared to the older groups. They did not benefit as much from the contingencies on the local level which was also found for the ASD participants as a group. It was suggested that this could be due to a more stable global bias, potentially due to an overintense attentional focus, and a higher accompanying cognitive load in those participants. Overall, ASD participants showed similar result patters to TD children.

### 8.2.4 Q2: The influence of stimulus presentation times in ASD compared to TD

This section examined whether LGP in ASD is influenced by stimulus presentation times and whether the effects differ from TD.

#### 8.2.4.1 Results

Note that due to the missing data in TD in the block LONG which was introduced at a later stage, the AmTD group only consists of 29 participants in this analysis (7 children, 7 adolescents, 15 adults). The focus of the result presentation will be on differences between ASD and AmTD (ANOVA factor sample group and its interactions).

*Summary of results:* The ASD group had higher RTs in LONG, and lower accuracy in MASK compared to the TD group. In MASK, the TD group had more global bias in RTs than the ASD group, whereas the ASD group had more global bias in accuracy. Overall, TD children had more global bias than ASD children. Whether or not ASD participants showed a global bias was dependent on the stimulus presentation duration. Children had no significant bias in any duration, adolescents had a significant bias in SHORT and LONG, adults had a bias in all durations.

Descriptive Tables can be found in Appendix G.1.1.1 (for RTs Table *G.2*, accuracy Table *G.3*) and G.1.1.3 (for BIs, Table *G.12*) for TD. For ASD see Appendix G.1.2.1 (for RTs Table *G.15*, accuracy Table *G.16*) and G.1.2.3 (for BIs, Table *G.25*). Tables with the inferential statistics can be found in Appendix G.2.2. (Table *G.30* and Table *G.31*).

##### *8.2.4.1.1 Reaction Times (*Table G.30*)*

The 3x2x3x2 repeated measures ANOVA with the factors duration, level, age group and sample revealed a significant interaction of Duration x Sample Group ($p$ = .021). In LONG, ASD reacted slower ($M$ = 841ms) than AmTD ($M$ = 755ms, $p$ = .034), while they did not differ in MASK and SHORT

($p$ > .05, Figure 8.16a). Further, the interaction Level x Age Group x Sample Group was significant ($p$ = .034), although it was n.s. in either group when analysed separately, $p_{ASD}$ = .107, $p_{TD}$ = .333). RTs to local and global trials did not differ significantly between samples or age groups (all $p$ > .05, Figure 8.16b). No other sample-specific effects were found. Further, significant were the main effect of age group ($p$ <.001), level ($p$ < .001) and duration ($p$ < .001), which was equivalent to the TD analysis.

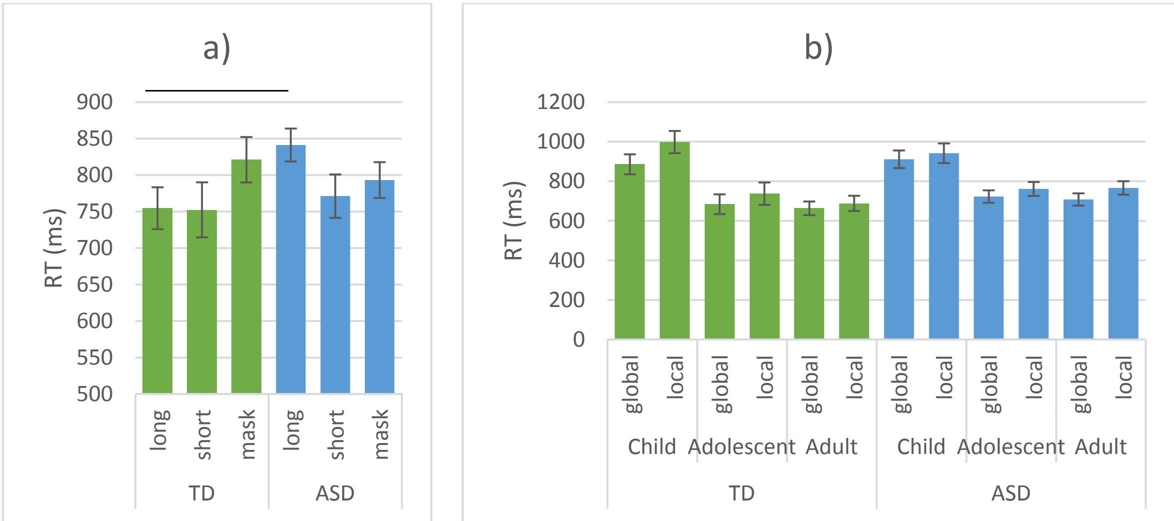



*Figure 8.16.* Visualisation of the interaction Duration x Sample Group (a) and Level x Age Group x Sample Group (b).
In a) significant differences between groups are indicated with —. In b) no significant difference between levels were found.

### *8.2.4.1.2 Bias Indicator (BI$_{RT}$,* Table G.31*)*

The 3x3x2 repeated measures ANOVA with the factors duration, age group and sample revealed only a significant interaction of Duration x Sample ($p$ = .034). The BI$_{RT}$ in MASK in ASD was significantly higher than in MASK in TD (Figure 8.17a). Further, Age Group x Sample Group was significant ($p$ = .019). TD and ASD only differed in the child group with TD having a more pronounced global bias (i.e. lower BI$_{RT}$) than ASD children ($p$ < .05, Figure 8.17b). No other effects of sample group were found.

In ASD only, Duration x Age Group was significant ($p$ = .013). Equivalent to the above RT analyses, the BI$_{RT}$ was not significant (BI = 1) in any condition in the child group (see Figure 8.18). In the adolescent group, the BI$_{RT}$ was only significant in LONG, whereas it was significant in the SHORT and LONG condition in adults ($p$ < .05).

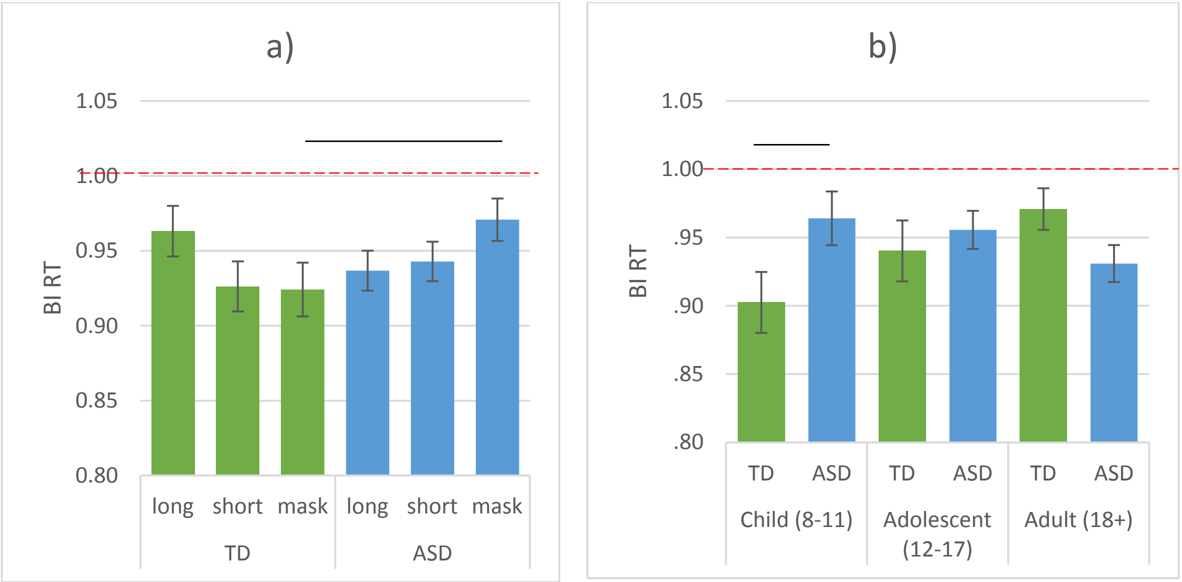



*Figure 8.17.* Visualisation of significant interactions Sample Group x Duration (a) and Sample Group x Age Group (b).

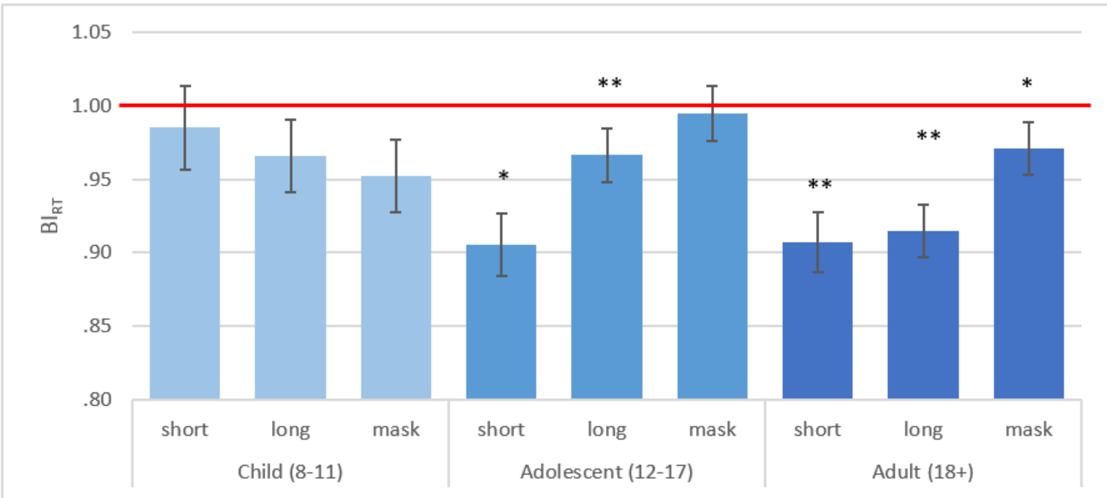



*Figure 8.18.* Bias indicator BIRT in the ASD group split by age group and duration condition.
The horizontal line indicates BI = 1 (no bias). BI < 1: global bias. BI > 1: local bias. Stars indicate the level of significance in one-sample t-tests against test value 1. *: $p \leq .1$; **: $p \leq .05$.

#### 8.2.4.1.3 *Accuracy (*Table G.30*)*

The 3x2x3x2 repeated measures ANOVA with the factors duration, level, age group and sample revealed a significant interaction of Duration x Level x Sample Group ($p$ = .035). In AmTD the interaction Level x Duration was not significant ($p$ = .549), whereas it was in ASD ($p$ = .001). Pairwise comparisons showed that the difference between accuracy to local and global trials was only significant in the ASD group in MASK ($p$ = .003, cf. Figure 8.19). Further significant were the interaction Duration x Sample Group, Duration x Level, the main effects duration, sample, and age group ($p < .05$). Overall, ASD ($M$ = 93.4%) performed less accurately than AmTD ($M$ = 96.2%, $p$ = .028). Children had the lowest accuracy ($p < .05$) followed by adolescents and adults who did not differ ($p > .05$).

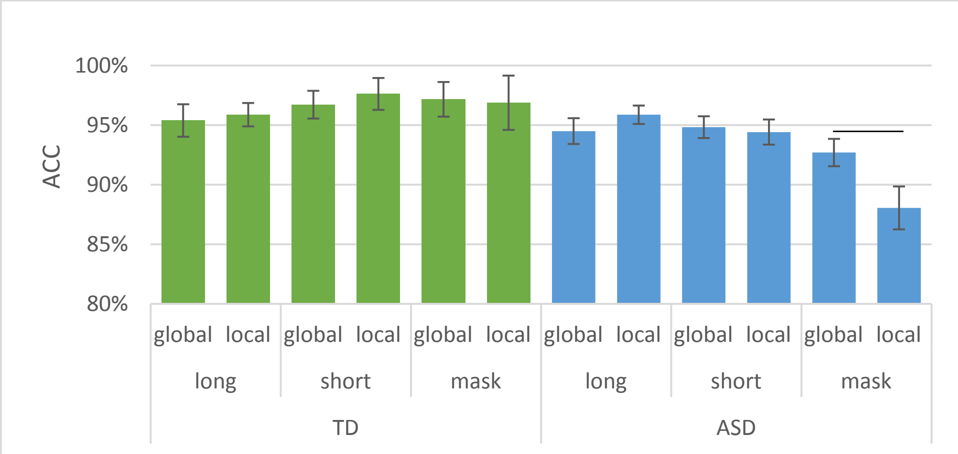



*Figure 8.19.* Accuracy data in AmTD and ASD participants in different stimulus durations. Significant comparisons are indicated with ─.

#### *8.2.4.1.4 Bias Indicator $BI_{ACC}$*

In terms of the $BI_{ACC}$, The 3x3x2 repeated measures ANOVA with the factors duration, age group and sample showed a significant interaction of Duration x Age Group ($p$ = .035). In children, the $BI_{ACC}$ was lowest in MASK ($M$ = .95), followed by SHORT ($M$ = 1.00) and then LONG ($M$ = 1.05, all $p < .05$). In the other age groups, no significant difference between duration conditions were found (all $p > .05$, cf. Figure 8.20a). Further, the main effect of sample was significant ($p$ = .031), with ASD showing slightly more global bias overall ($M$ = .985) than AmTD ($M$ = 1.008, Figure 8.20b). Lastly, duration was a significant main effect ($p < .001$, significantly more global bias in MASK than in the LONG, $p$ = .027, and SHORT, $p$ = .008).

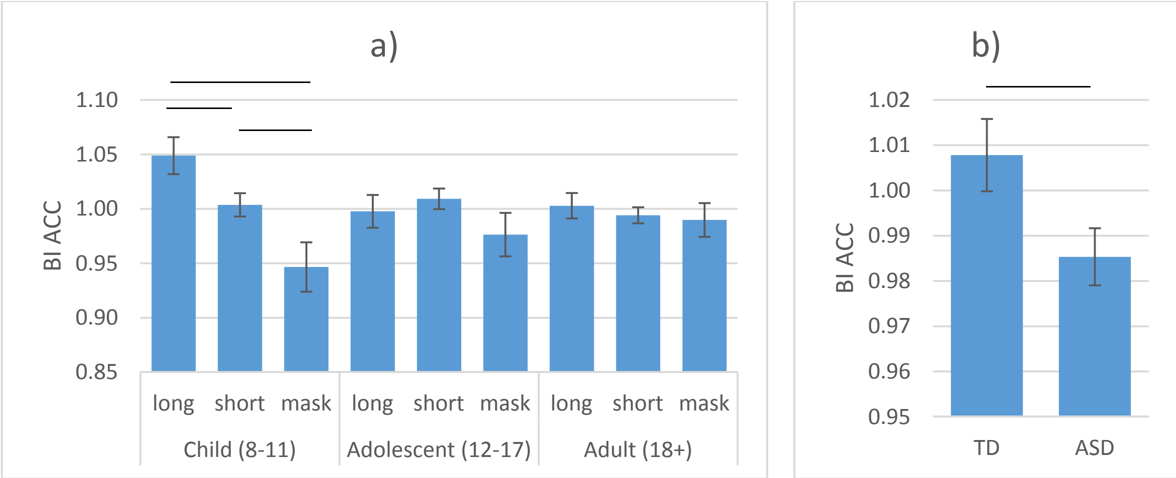



*Figure 8.20.* Bias Indicators $BI_{ACC}$ in duration conditions, age groups and samples.
a) Mean $BI_{ACC}$ per age group and stimulus duration condition. a) Mean $BI_{ACC}$ for AmTD and ASD. — indicates significant differences ($p < .05$).

#### 8.2.4.2 Summary and Discussion

The analyses showed that stimulus durations had different effects in different age groups in ASD. However, the results were different than expected: When the $BI_{RT}$ was examined, children showed no significant bias in any condition, adolescents only in two out of three (LONG, SHORT), and adults in all three conditions. Thus, processing biases appear to become stronger with age in ASD. Interestingly, the EGA analysis of the influence of AQ scores in TD (Section 8.1.5) had shown that the (older) higher AQ groups also showed more pronounced biases than the lower AQ group. Overall, the ASD group had a more global bias ($BI_{ACC}$) than TD, showing less accurate responses to local than global trials. More specifically, in MASK, ASD individuals had a global bias in accuracy ($BI_{ACC}$; this was also found in TD children); however, TD had a more global bias regarding RTs ($BI_{RT}$) in this condition compared to ASD. This shows a different response styles between TD and ASD which became most apparent in the most challenging block. Therefore, depending on what studies assess, accuracy or RT, they might find more bias in TD or ASD as both groups had a bias but it was reflected differently in the data.

Furthermore, while TD and ASD did not differ regarding RTs in the blocks SHORT and MASK, ASD responded significantly slower in LONG. Studies using long stimulus durations might therefore mistakenly conclude that in ASD the task posed higher cognitive demand which led to longer RTs compared to TD, although their findings might have been due simply to the particular stimulus presentation times in the task. If shorter durations were chosen, conclusions might differ.

### 8.2.5 Q4: Priming and Switching in ASD compared to TD

This section examined the effect of priming on LGP in ASD in comparison to TD and whether factors like age, processing level, stimulus duration and contingencies influenced the results.

#### 8.2.5.1 Results

The analyses revealed many significant main effects and interactions; however, only those relevant for the PESC analysis, i.e. main effects of priming and its interactions, will be reported as the other effects have been covered in the previous analyses. We will further focus on differences between TD and AmTD (main effect of sample group and its interactions).

*Summary of Results:* Overall, the analysis showed only small influences of age, stimulus duration and contingencies on the ability to switch between processing levels and benefit from priming. The extent of PESC in RT and accuracy did not vary much between ages or samples, although children had higher $PESC_{RT}$ than the older groups. In ASD, $PESC_{RT}$ were higher for global trials than local (and there was the same tendency in $PESC_{ACC}$). No RT difference was found between identity and level-priming in children and adolescents, but in adults (identity priming was associated with faster RTs). RTs to level- and identity-priming further differed in LONG but not the other durations.

Descriptive Tables for RTs and accuracy can be found in Appendix G.1.1.2 (Table *G.4* to Table *G.11*) for TD. For ASD, see Appendix G.1.1.2 (Table *G.4* to Table *G.24*). Tables with the inferential statistics can be found in Appendix G.2.3 and G.2.4 (Table *G.32*, Table *G.33* and Table *G.35*).

##### *8.2.5.1.1 Priming and Stimulus Duration*

*Reaction Times (*Table G.32*)*

A 3x2x3x3x2 ANOVA (Duration x Level x Priming x Age Group x Sample) revealed no sample-specific effects. However, there were significant interactions that had not been significant in the

TD-only analysis: Age Group x Priming ($p$ = .003) and Duration x Priming ($p$ = .012, both interactions were also significant when only the ASD group was analysed).

Post-hoc examinations of the Age Group x Priming interaction showed that in all age groups, RTs to switch trials were higher than with level- and identity-priming ($p \leq .01$). There was no difference between level-priming and identify-priming in adolescents ($p$ = .765) or children ($p$ = 1), but in adults ($p$ = .011, Figure 8.21a). The examination of the Duration x Priming interaction showed that in LONG, RTs in switch trials were slowest, followed by level-priming and then identity-priming (all $p < .001$, Figure 8.21b). In SHORT and MASK, switch trials had slower RTs than both priming conditions ($p < .001$), but those did not differ significantly ($p > .17$).

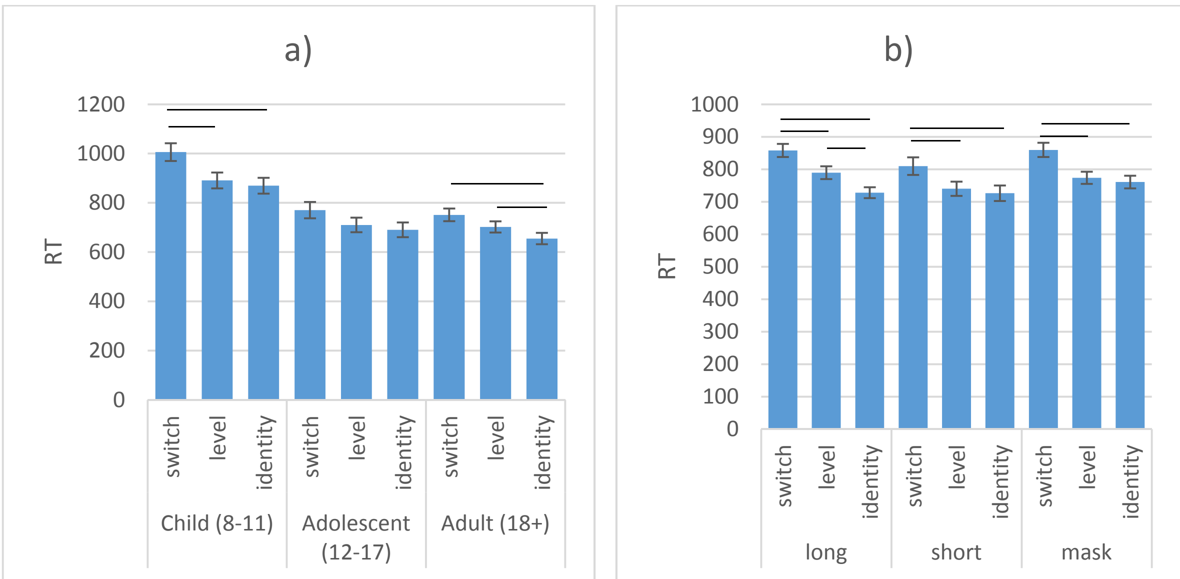



*Figure 8.21*. Visualisation of the interactions Age Group x Priming (a) and Duration x Priming (b). Means and SE are presented.

### *Priming Effects / Switch Costs in RTs (*Table G.33*)*

A 3x2x3x2 ANOVA (Duration x Level x Age Group x Sample) with the DV $PESC_{RT}$ revealed only a significant effect of age group ($p$ = .004, equivalent to the TD-only analysis). The child groups had higher $PESC_{RT}$ compared to the older groups (child $M$ = 121ms vs adolescent $M$ = 69ms, $p$ = .010, child vs adult $M$ = 72ms: $p$ = .007; Adolescent vs adult: $p$ = 1). Despite the main effect of level being significant in ASD ($p$ = .027), it was not significant when both samples were analysed together ($p$ = .098). In ASD, $PESC_{RT}$ for global trials ($M$= 116ms) were higher than for local trials ($M$ = 82ms).

*Accuracy (Table G.32) and Priming Effects / Switch Costs (Table G.33)*

A 3x2x3x3x2 ANOVA (Duration x Level x Priming x Age Group x Sample) examining the effects on accuracy revealed no sample-specific effects of priming.

Similarly, when analysing the $PESC_{ACC}$, a 3x2x3x2 ANOVA (Duration x Level x Age Group x Sample) revealed no significant effects on $PESC_{ACC}$. In ASD the main effect of level was not far from significant ($p$ = .069) which was in contrast to TD ($p$ = .729) and the overall analysis ($p$ = .414): there was a tendency for higher $PESC_{ACC}$ in global trials ($M$ = 3.9%) than local trials ($M$ = 2.2%), i.e. higher PESC when switching from the local to the global level.

#### *8.2.5.1.2 Priming and Contingencies*

*Reaction Times and Accuracy (*Table G.35*)*

For the DV RT, a 2x2x2x3x2 repeated measures ANOVA with the factors level, contingency (50, 80%), priming, age group, and sample showed no sample-specific effects of priming.

Similarly, the accuracy analysis with a 2x2x2x3x2 repeated measures ANOVA with the factors level, contingency, priming, age group and sample also showed no differences between AmTD and ASD.

### 8.2.5.2 Summary and Discussion

The analysis of the CE resulted in the findings that in ASD as a group and in children as a group (TD+ASD) accuracy in local trials did not benefit as much from increased contingencies (which have more primed trials than switch trials) as did accuracy in global trials. Similar could be expected when analysing level- or identity-priming vs level-switch on a trial-by-trial basis: priming would be more beneficial for accuracy on the global level (and PESC therefore higher) compared to the local level. Indeed, in ASD, RTs to switch trials were significantly higher when switching from local to global than when the level remained global on two consecutive trials, and there was a tendency for the same effect in accuracy. This effect was missing in TD. The previous analyses in TD had shown, however, that TD children did not benefit from priming on the local level, as accuracy was relatively constant across all priming conditions, whereas there were significant PESC on the global level.

The analyses in this section further showed that children had significantly higher $PESC_{RT}$ than the older groups which was expected given that the ability to switch processing levels is thought to increase with age (Huizinga et al., 2010).

It was further predicted that individuals with ASD might show higher PESC than TD due to the difficulties in EF and a less mature cognitive system. However, the analysis did not reveal a significant main effect of sample group, neither in RTs ($p = .084$), nor in accuracy ($p = .691$). This was equivalent to the findings of Hayward et al. (2012) and Richard and Lajiness-O'Neill (2015), although Richard and Lajiness-O'Neill concluded that shifting in ASD takes more effort than TD. Van Eylen et al. (2011) argue that problems with shifting only become apparent in ASD in tasks with limited explicit instructions and a high degree of disengagement required for the switch. Most experimental tasks, therefore, show intact cognitive flexibility, whereas more natural settings show impaired shifting.

In LONG, the difference between switch and nonswitch trials was significant in LONG in all age groups and both samples. This was in contrast to Hayward et al. (2012) who did not find significant PESC in their G50L50 block (the equivalent to our LONG block), neither in TD nor in ASD. A possible reason for these findings might be that their stimuli were filled-in local and outlined global elements, whereas we used outlined elements on both levels. List et al. (2013) found that level-priming was only effective in outlined but not filled-in stimuli. Thus, potentially, Hayward et al. did not find significant PESC, because level-priming was not as successful with their stimuli which reduced the overall priming effect. Although the authors did not differentiate between level and identity priming, this explanation seems reasonable.

Another discrepancy in findings between both studies was that Hayward et al. reported higher $PESC_{RT}$ for local than global trials, whereas in our study there were no significant differences in PESC between levels overall but a tendency in ASD for higher PESC in global than local trials (significant for $PESC_{RT}$, close to significant in $PESC_{ACC}$). In the full TD sample (Section 8.1) it was further demonstrated that TD children showed higher $PESC_{ACC}$ in global than local trials in the LONG block. Similarly, Hubner and Volberg (2005, in TD adults) and Soriano et al. (2018, in ASD children but not TD) had shown that shifting attention from local to global (i.e. zooming out in contrast to zooming in) was more difficult for participants. Differences in switch ability have been reported in ASD subtypes: Rinehart, Bradshaw, Moss, Brereton, and Tonge (2001) demonstrated higher switch costs in Autism, but not AS, when switching from local to global, while Katagiri et al. (2013) found that switching from local to global was also more difficult for adults with AS. Katagiri et al. interpreted this as indication for greater local interference compared to the control group while the groups did not differ in global-local switches. The authors explained the findings with a selective problem in local inhibition in ASD due to enhanced local processing (Mottron et al., 2006), although their experiment did not demonstrate enhanced local processing in ASD per se (no sample specific effect of level on RTs or accuracy, like in the current study). This explanation might, thus, also apply to the current findings.

Stimulus duration did not influence switch costs overall, although there were duration-specific differences in the priming conditions. In LONG, level-and identity priming differed significantly, with identity-priming leading to higher accuracy than level-priming. Further, adults but not the younger age groups showed this effect also in the other duration blocks. It seems that identity-priming is stronger when the cognitive system is more mature (as in adults) or when there is ample time to process a stimulus. Although this was found for the total sample (ASD + AmTD), the effects were mainly carried by the ASD group where the interactions were significant in a separate ASD-only ANOVA (in contrast to TD where the interactions were nonsignificant). In PECOG, we suggested that identity priming represented a perceptual aspect, whereas level-priming was a more cognitive aspect of the CE. Building on this, the current findings would suggest that the cognitive system is independent of age and duration manipulations, whereas the efficiency of the perceptual system develops with maturity. However, this would an implausible conclusion and thus further research is required to clarify the issue.

### 8.2.6 Q5: The Relationship between LGP and Autistic Traits in ASD and TD

In this section, the relationship between LGP and autistic traits (for ASD and all participants) was examined by means of a correlation analysis and EGA.

### 8.2.6.1 Results

*Summary of results:* Although the correlation analyses revealed higher local $BI_{ACC}$ with higher AQ scores in ASD, this was not confirmed by the EGA which showed no differences in the BI between groups with high AQs and low AQs in ASD. Overall, the analyses revealed that in older participants (TD+ASD), there was a negative relationship between AQ scores and the $BI_{RT}$, indicating that higher AQ scores went along with more global bias regarding RTs. This relationship was, however, mainly carried by the TD group.

Descriptive Tables can be found in Appendix G.1.1.3 (Table *G.13* and Table *G.14*) for TD and G.1.2.3 (Table *G.26* and Table *G.27*) for ASD. Tables with the inferential statistics of the EGA can be found in Appendix G.2.1. (Table *G.36*).

#### *8.2.6.1.1 Correlation Analysis*

Similarly to the TD analysis, a correlation analysis between the BI and AQ scores was conducted in ASD. No significant correlations in any age group were found between the $BI_{RT}$ and AQ scores (all $p > .05$). When looking at the $BI_{ACC}$, moderate positive correlations were found in adults between the $AQ_{total}$, and the $BI_{ACC}$ in SHORT and LONG but not in MASK, indicating a slightly stronger local perception bias regarding accuracy with higher AQ scores (cf. Table 8.9).

Correlations were also calculated across both samples (but split into younger/older age groups). In adults, there was a highly significant negative correlation, $r = -.458$, $p = .002$, explaining 21% of the variance in $BI_{RT}$ and AQ Scores (cf. Figure 8.22). This was less than for TD adults alone ($R^2 = 35\%$, see Section 8.1.5.1) which is consistent with the fact that no significant correlation was found for ASD adults alone.

Table 8.9

*Correlations between the BIRT and BIACC in different experimental blocks and thte AQtotal in each age group for ASD and age-matched TD participants (VISTA study)*

| | | | ASD | | | | age-matched TD | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | child | adolescent | adult | overall | child | adolescent | adult | overall |
| $BI_{RT}$ | G20L80 | r | | | | | | | | |
| | | rho | | | | | | | | |
| | Short | r | | | | | | | -.637** | |
| | | rho | | | | | | | -.620** | |
| | G80L20 | r | | | | | | | | |
| | | rho | | | | | | | | |
| | long | r | | | | | | | | |
| | | rho | | | | | | | | |
| | mask | r | | | | | | | | |
| | | rho | | | | | | | | |
| $BI_{ACC}$ | G20L80 | r | | | | | | | | |
| | | rho | | | | | | | | |
| | Short | r | | | .477* | | | | | |
| | | rho | | | .524* | | | | | |
| | G80L20 | r | | | | | | | | |
| | | rho | | | | | | | | |
| | long | r | | | .523* | | | .779* | | |
| | | rho | | | | | | | | |
| | mask | r | | | | | | -.704 | | |
| | | rho | | | | | | | | |

*Note.* Only significant correlations (Pearson's *r*, Spearman's *rho*) are reported. *: $p < .05$; **: $p < .01$

#### *8.2.6.1.2 Extreme Group Approach (*Table G.36*)*

Equivalent to the analyses for TD the ASD participants were split into a younger (child) and older (adolescents and adults) group and extreme groups were selected based on the first and third tertile of the AQ scores in those age groups. In the younger ASD participants (n = 12) the low AQ group included scores up to 108, and the higher AQ group scores over 116 (n = 4 in either group but only three who completed all blocks). In the older participants, the cut-offs were 83 (low AQ) and 102 (high AQ, n = 13 in either group). The extreme groups were included in two 5x2x2 ANOVAs with the factors block (G20L80, G50L50, G80L20, LONG, MASK), age group (younger, older) and AQ group (lower, higher), once for the $BI_{RT}$, once for $BI_{ACC}$. Both ANOVAs with the DV $BI_{RT}$ and $BI_{ACC}$ revealed only a significant effect of block ($p < .001$), thus no differences between high and low AQ groups.

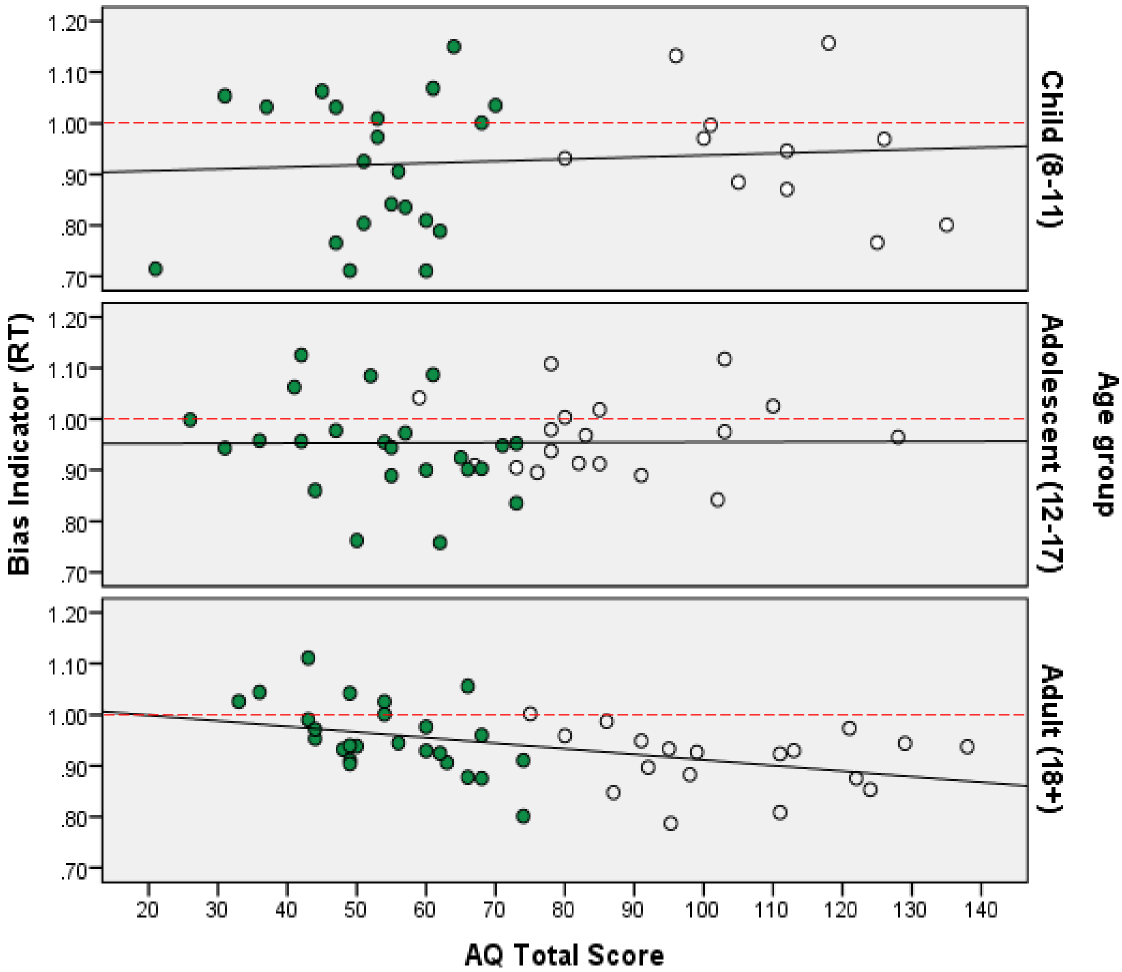



*Figure 8.22.* Relationship between the AQ Total Score and Bias Indicator BIRT (standard condition) in each age group.
Horizontal lines (- - -) indicate BI = 1: no bias. BI < 1: global bias. BI > 1: local bias. Explained variance $R^2$ in per group by linear regression line: Child = 2.5%, Adolescent = 0.4%, Adult = 21.4%. A quadratic regression line explains Child = 26.4%, Adolescent = 2.0%, Adult = 31.1%. Dark filled markers represent TD cases, white filled markers represent ASD participants.

When all participants were examined together (ASD+TD) by including the additional factor sample group in the ANOVAs, the analysis regarding $BI_{RT}$ showed a significant 4-way interaction of Block x Sample Group x Age Group x AQ Group ($p$ = .029) which was explored further. There were no significant differences between AQ groups and between sample groups in the younger participants as well as between any of the ASD groups (all $p$ > .05). However, the TD older group with lower AQ scores had significantly higher biases in SHORT ($BI_{RT}$), LONG ($BI_{RT}$) and MASK ($BI_{ACC}$) compared to the groups with higher AQ scores (TD and both ASD groups, cf. Figure 8.23).

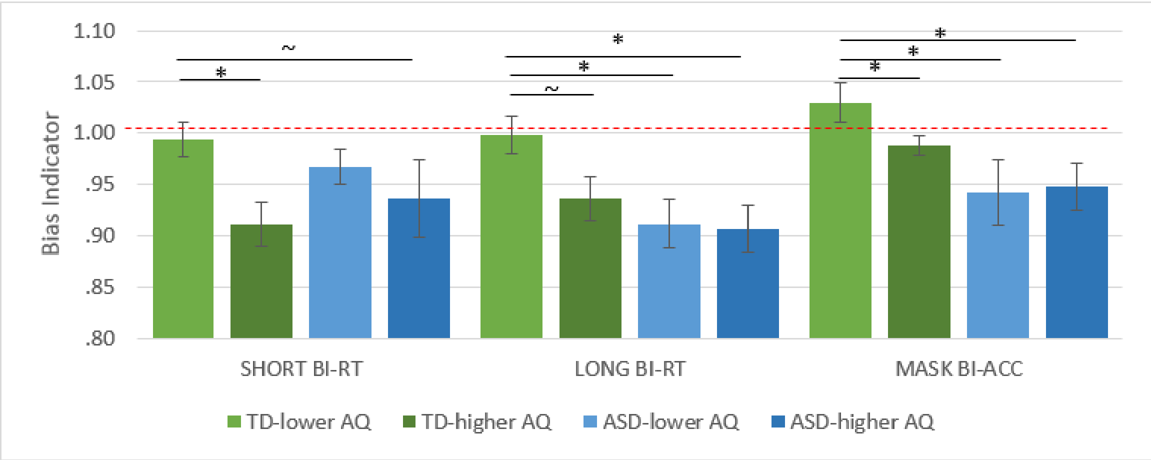



*Figure 8.23.* Comparison of Bias Indicators in the TD groups with lower and higher AQ scores and the ASD groups with lower and higher AQ scores in older participants.
— indicate pairwise comparisons with $*p < .05$, $\sim p < .1$. The red dotted line indicates BI = 1, i.e. no bias, whereas BI < 1 is a global bias. As apparent, the lowest AQ group had less global bias (or no bias) compared to the highest AQ group.

#### 8.2.6.2 Summary and Discussion

Although the analysis of both samples together in a correlation approach showed a significant negative correlation for the adult group ($R^2$ = 21% variance explained: more global bias $BI_{RT}$ with higher AQ-scores); this was mainly carried by the TD group ($R^2$ = 35%), as there was no significant correlation in ASD adults alone ($R^2$ = 4.8%). Despite ASD adults showing a moderate correlation between a bias in accuracy ($BI_{ACC}$) and AQ-scores (higher AQ-scores went along with more local bias) the EGA showed no difference in bias between the lower and higher AQ groups in the clinical population. Both ASD AQ groups had a comparable bias, which was also similar to bias in the high AQ TD group. Only the low TD group showed more global bias (cf. Figure 8.23). It appears that there is a relationship between autistic traits and bias, but only up to a certain amount of autistic traits. After that, the relationship levels out (see Figure 8.24).

Although a growing number of studies examine the relationship between AQ scores and processing bias in TD, to our knowledge investigations assessing the relationship in ASD are still rare. McKenzie et al. (2018) conducted a large study with 256 participants aged 16 to 73 (*M* = 30 years) of which 40 had a reported or self-reported ASD diagnosis. The participants completed the AQ questionnaire, an LGP task and an emotion recognition task so that relationships between those could be explored. The authors

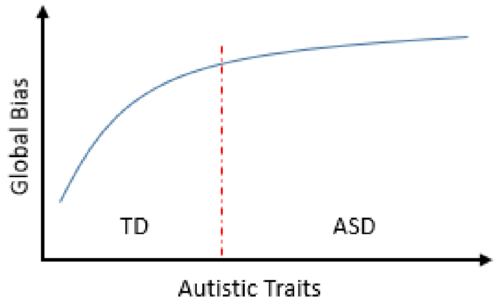



*Figure 8.24.* The suggested relationship between autistic traits and global bias in the current task.

did not differentiate between non-ASD and ASD participants in the analysis and found no significant relationship between the AQ scores and the local processing measures (neither when using only the scale Attention to Detail, AtD, nor with using only the other AQ subscales but without AtD). A meta-analysis from Cribb et al. (2016) concluded that studies using extreme groups found superior local processing, whereas those that used AQ-scores as a continuous variable did not; probably due to reduced statistical power. Unfortunately, McKenzie et al. did not give information on how many of the participants were adolescents, how many adults, and also not whether results changed when participants with ASD (and consequently high AQ scores) were included/excluded in the analysis. In the current study, we only found a significant relationship between AQ scores and processing biases in the older participant group and only in the non-ASD group. To our knowledge, research examining the relationship between autistic traits and LGP in younger age groups was so far missing (see also Cribbs et al., 2016). However, due to the very small sample sizes of the young groups in the current study, the null-effect in those groups must be interpreted with caution.

The lack of a relationship between AQ scores and LGP in ASD could also be the analysis method: A TD study by Richmond, Thorpe, Berryhill, Klugman, and Olson (2013) found that AtD and the scale ‘social interaction’ (SI) had opposing relationships, in their case, to visual WM: while higher scores on SI were associated with poorer WM performance, higher scores on AtD went along with higher WM performance. Thus, including both scales in the overall AQ score could have masked those effects. Subsequent research studies examining the relationship between LGP and AQ Scores should therefore also discriminate between the subscales of the AQ and their association to LGP.

### 8.2.7 Summary: Local and global processing in ASD compared to TD

This study examined different aspects of LGP in ASD, including processing biases, their flexibility on a block- and trial-by-trial basis, and the influence of stimulus presentation times. 50 participants aged 8 to 54 with a diagnosis of ASD completed the same hierarchical figures tasks as the TD participants in Section 8.1 and were compared to an age-matched control sample. Some predictions were met, other results were unexpected.

The main findings were that overall, ASD and TD had comparable global biases which were not modulated by participants' ages. The absence of a local bias is in line with previous findings (Hayward et al., 2012; Iarocci et al., 2006; Mottron et al., 2003; Plaisted et al., 1999) and evidence against the Weak Central Coherence Theory (WCC, Frith, 1989) which claims that individuals with ASD showed reduced global processing and/or enhanced local processing. In its updated version, Happe and Frith (2006) broadened the theory by arguing that individuals with ASD only have a local processing preference (or cognitive style) but are able to process stimuli globally. Nevertheless, according to this, ASD participants would still have been expected to exhibit a local bias in our task. The (original) theory further assumed that WCC was universal in ASD and applies to all individuals which has been disproved, for example, by Caron et al. (2006) and Booth (2006). Perhaps, the current ASD sample consisted in the majority of non-WCC individuals leading to the current results.

Research comparing biases across ASD age groups is limited. Scherf et al. (2008) found that global bias increased with age in TD but not ASD which was not replicated in the current study. Possibly, differences in the task lead to the discrepancy of results.

In Chapter 2, we discussed the possibility that local and global processing are not in an opposing relationship to each other but indeed lie on two separate continuums with strong and weak ends for global as well as for local processing. According to this view, individuals can process efficiently on either, both or none of the processing levels and there is variability on how flexible they can shift between levels (Evans et al., 2013; Happe & Booth, 2008; Happe & Frith, 2006; Huizinga et al., 2010;

Pletzer et al., 2017; Soriano et al., 2018). In the current study, only small differences were found in shifting abilities between TD and ASD, while switching was not affected by stimulus durations or contingencies. The RT data analysis showed that TD children but more ASD children had slightly less flexibility in their bias, whereas the accuracy data analysis revealed that TD and ASD children, as well as ASD overall, had less benefit from the CE in local trials. In general, the block G20L80 lead to lower accuracy in ASD and slightly increased local bias in children.

Some differences between samples were found in the switch cost analysis: Children showed higher PESC than the older groups, but ASD overall did not differ in the amount of PESC from TD (although the $PESC_{RT}$ was not far from significant). ASD did, however, show level-specific effects with PESC being higher when switching from local to global and vice versa. Similarly, in LONG children showed higher $PESC_{ACC}$ for global than local trials. Other research (TD: Hubner & Vorberg, 2005; ASD: Katagiri et al., 2013; Mann & Walker, 2003; Rinehart et al., 2001) also demonstrated that zooming out (shifting from local to global) was more challenging than zooming in (from global to local). This could be interpreted as a deficit in broadening the spread of attention (as in Mann & Walker, 2003) or a selective problem with inhibiting local information in ASD participants and TD children to due enhanced local processing (as in Katagiri et al., 2003). Fittingly, the results in Section 8.1 pointed towards an automatic global processing bias in TD children but a voluntary local preference in some of those children. Together, these results give partial support to the executive dysfunction theory for ASD (Ozonoff et al., 1991) in that cognitive flexibility, attention switching and inhibition are less efficient than in TD. The fact that overall, ASD participants performed similarly to TD children points towards a developmental delay in that group. A developmental delay in ASD has also been reported, for example, by Van Eylen et al. (2018) in a (global) coherent motion task. Furthermore, we concluded that despite showing overall similar performance to TD, the underlying processes leading to this performance are likely to be deviant (more effortful / cognitively taxing) in ASD (Cowan et al., 2010; Iarocci et al., 2006; Richard & Lajiness-O'Neill, 2015). Future research could explore this further.

The comparison of stimulus presentation times revealed some interesting findings which are relevant for comparing different studies: First, both, TD and ASD showed global biases in the most challenging block (MASK) but the presentation differed between samples: In TD the bias concerned RTs, in ASD it concerned accuracy. Second, TD and ASD showed comparable RTs and accuracy in the blocks with shorter stimulus durations; however, in the block with the longest duration, ASD responded slower than TD. This is usually interpreted as indicating higher cognitive demand (e.g. Chahboun et al., 2016) but unlikely in the current case as it was the least challenging block. Together, the results indicate that study outcomes are influenced by stimulus presentation times and the assessed variables, which thus need to be considered carefully when planning and evaluating research.

The examination of the association between perception biases and autistic traits in this and the previous Section 8.1 revealed that in older TD participants more autistic traits went along with more global bias, while this relationship was not continued at even higher AQ scores the ASD sample. The finding for TD on its own was surprising, given that previous research exclusively reported that more autistic traits were associated with enhanced local performance/reduced global performance (Crewther & Crewther, 2014; Cribb et al., 2016; Grinter et al., 2009; Van Boxtel & Lu, 2013). We could identify only one other study (McKenzie et al., 2018) that included ASD participants when analysing the relationship between AQ scores and perception biases; however, they did not differentiate between ASD/non-ASD, or different age groups, and found no significant relationship between autistic traits and local processing. Milne and Szczerbinski (2009) have demonstrated that tasks commonly used to assess LGP, are in fact measuring slightly different aspects: a factor analysis identified seven different factors including disembedding, global bias, cognitive flexibility, and perceptual speed. Thus, the task used to obtain an LGP measure which is then correlated with AQ scores is likely to play a role in the outcome. Potentially, some tasks are more likely to elicit or detect a local or global bias than others and thus will/won't show significant associations. Given the discrepancies in results between this and previous research, it remains of interest to examine the issue in future studies, e.g. by including more representative, larger sample sizes with a wider age range, as well as a more varied battery of local/global tasks.

#### 8.2.7.1 Limitations

There were a few limitations in this study that need to be considered. The first one concerns specific challenges that are associated with testing participants with ASD. For example, individuals with ASD have previously been reported to interpret task instructions more literally or be very specific about the instructions (Scott, submitted, as cited in Happe & Frith, 2006; and see also Discussion I Section 9.2.5.2). In the current experiments, some participants with ASD questioned the experimenter's explanations of the stimuli and argued that the diamond shape was not a diamond but indeed a tilted square, as a diamond shape should be more elongated. Although they agreed to treat the shape as a diamond and to press the according button, they did not do so readily. This could have influenced their overall performance.

Second, when analysing switch costs, Hubner (1997) and Soriano et al. (2018) only included switch/prime trials if the current and previous trial had a correct response, whereas we only considered the current trial. It is possible though, that a wrong response in the previous trial impacted the next one and distorted the data for the switch cost analysis (post-error slowing, Wessel & Aron, 2017). In future studies examining switch costs, we recommend considering also the accuracy in previous trials.

Third, in the EGA with high and low AQ groups, the TD child groups only consisted of seven participants with only four of those having complete data sets, while there were only three in the low AQ ASD group. This limited the power of the analyses and also generalisability of results. Although the higher and lower AQ groups could have been formed by splitting the samples at the median in order to receive larger groups (as in Takahashi & Gyoba, 2012), it was decided against this in order avoid potential misclassification of individuals around the median (cf. Graham & Madigan, 2016).

Forth, the assessment of child participants included more and longer breaks between and within blocks (after every 20 trials) compared to the older participants who often skipped the breaks completely by choice. Consequently, children might have been more likely to reset their approach and change the response strategy from one block to the next while the adults maintained a consistent response strategy. This could have potentially impacted the effects of contingencies. Future studies should include obligatory breaks of a certain duration for all participants or remove breaks in order to keep the assessments more consistent and reduce potential task-independent effects on the data.

## 8.3 Conclusion of Chapter 8

To conclude, the examination of the TD sample showed that all age groups had a global bias, while it was descriptively slightly higher in children. Children showed poorer performance (RTs and ACC) on the local and global level compared to older participants. All age groups were able to shift their bias depending on the contingencies of local and global trials, but children showed somewhat less flexibility. Switching ability on a trial-by-trial basis also improved with age and switch costs reduced. It was suggested that despite the presence of an automatic global precedence effect, some children (still) have a local processing preference when given the choice (in long exposure times). With age, a global preference would become prevalent.

The ASD group showed overall comparable performance to TD, but more in depth analyses revealed certain differences. While the global bias was relatively stable in TD across different exposure times and age groups, in ASD, biases became more pronounced with age. Fittingly, in older TD participants, more autistic traits went along with more pronounced biases (and the low AQ group showed little to no bias); however this was only true up to a certain amount of autistic traits, as there was no linear relationship between the biases and clinical amounts of autistic traits in the ASD group.

Although a CE was found in ASD, the participants showed less bias flexibility on the local level, which was also found in the overall child group. It was suggested that despite ASD participants having a certain degree of cognitive flexibility, the process was more effortful for participants with ASD than in TD. Participants with ASD and children also showed higher switch costs when switching from local to global. These results could indicate increased local interference or difficulties in broadening the spread of attention.

Overall, a final conclusion about developmental delay or deviation regarding LGP in ASD cannot be made based on the current results, although the majority of the findings suggested a developmental delay in ASD due to child-like performance. The Weak Central Coherence Theory (based on which more local bias would have been expected in ASD) was not supported by the findings, whereas the

Executive Dysfunction Theory received partial support. Nevertheless, not all findings can be accounted for by either of the theories.

# 9 Language processing in typical and atypical development (LANTA)

In the last two chapters, local and global processing (LGP) in the visual domain in TD and ASD was examined. In this chapter, the results of the studies examining local and global LANguage processing in Typical and Atypical development will be presented (LANTA study). First, Section 9.1 will cover the findings in typically developing children, adolescents and adults, while in Section 9.2 language processing in ASD will be thematised and compared with typical development. The chapter concludes with a summary of the findings regarding local and global language processing (LGLP) in TD and ASD and limitations to this research.

## 9.1 Local and global language processing in typical development

### 9.1.1 Introduction

In the literature review in Chapter 4 it was discussed how according to Newport's (1990) *Less is More hypothesis*, children start to learn a language by focusing on separate elements of that language, i.e. local details, whereas later on the focus shifts to integration and perception of more complex wholes like words, sentences and larger text. The skill for such a local componential analysis is lost in older individuals which is, for example, apparent in adult learners of second languages who, in most cases, never reach full native speaker level. They can, however, gain a level comparable to native speakers in global aspects of language.

LGLP can be split into more and less local or global aspects. Thus, a large variety of tasks has been developed throughout the years to measures those aspects. Local tasks, for example, tap into morphology, syntax and simple grammar (Vulchanova, Talcott, Vulchanov, & Stankova, 2012; Vulchanova, Talcott, Vulchanov, Stankova, et al., 2012). Further, single words, e.g. ambiguous words, i.e. words that are either spelt (homographs) or sound the same (homophones) but have two or more distinct meanings (e.g. BANK) can also be used to assess local processing skills. When included in a sentence (e.g. He fished from the BANK), these words can be used to assess the extent to which the context of the sentence is considered during the processing of the ambiguous word (Frith & Snowling, 1983; Norbury, 2005a). There is disagreement amongst researchers whether or not ambiguous sentence tasks represent global or indeed local processing. For example, Jolliffe and Baron-Cohen (1999) argue that short texts between one to three sentences should be classed as local coherence as the sentences can be held in short-term memory at one time (like in the task AMBSENT in this study), whereas longer text (five or more sentences) would require to global coherence (like in the task SENTORD). For other researchers, however, ambiguous sentence tasks were usually classed as global processing (Frith & Snowling, 1983; Happe, 1997) or they did not differentiate between local and global processing but only referred to it as use of context/contextual processing (Norbury, 2005).

In the literature review in chapter 4, the distinction was made between local processing, local coherence, global processing and global coherence (Figure 4.1 on page 61) and the results of various studies assessing LGLP in (mainly) ASD were discussed. In the current chapter, some of the tasks from those studies have been adapted in order to examine a cross-sectional sample of TD individuals and to determine trajectories of LGLP in normal development which later on will be used for the comparison with individuals with ASD. The tasks selected for this purpose were:

1) AMBWORD: A picture verification task with single ambiguous words (based on Norbury, 2005). Participants had to decide whether the picture that they saw could represent the meaning of the word they had heard (e.g. "BANK" → riverbank picture). Pictures could depict the dominant, subordinate or a neutral (unrelated) meaning. This was classed as a local task as it involved single words in isolation.
2) AMBSENT: A picture verification task with sentences containing ambiguous words (based on Norbury, 2005). The task for the participants was the same as in AMBWORD, but here they heard full sentences (e.g. He stole from the BANK). Through small variations in the sentences, use of context for facilitation of relevant and suppression of irrelevant meanings could be examined, separately for dominant and subordinate meanings of the ambiguous words. This was classed as a local coherence task

3) SENTORD: A sentence ordering task in which sentences had to be arranged so that they resulted in meaningful stories (based on Jolliffe and Baron-Cohen's global integration task, 2000). One condition was classed as a local task as local (temporal) cues were provided ("in the morning", "in the evening"). The other condition was classed as a global coherence task, as no such cues were present. In the temporal condition, participants could rely on the cues and order the sentences based, for example, on a chaining technique. In the coherence condition, participants had to interpret the information and relate each sentence to the context of the other sentences.
4) SENTCOMP: A sentences completion task where participants were presented with incomplete sentences (e.g. He went hunting with a knife and…) and had to provide a completion for them (Booth & Happé, 2010). Global completions (e.g. gun) fit the whole sentence stem whereas local ones only took the last few words into consideration (e.g. fork). Participants were not made aware of this distinction but were told that there were no right or wrong answers. This task assessed preferred processing styles in participants.

In the literature review in Chapter 2, it was discussed that local and global processing are likely not to be on two ends of the same continuum, but develop alongside each other. For example, Happe and Frith (2006) reviewed over 50 empirical studies and concluded that processing of both levels improved with age. Various authors argued that it is not the LGP per se in which individuals, for example, of different ages, differ, but the ability to switch flexibly between processing levels and to select the most appropriate one for the given task (e.g. Huizinga, Burack, & Van der Molen, 2010; Kholodnaya, 2002, as cited in Kozhevnikov, 2007; Niaz, 1987). We would therefore not expect to find a trade-off between local and global processing in the language tasks but that some participants perform well on local as well as global tasks. Children are likely to show poorer performance in local as well as global language tasks compared to older age groups, as their processing abilities are still developing. However, it might be that they show more of a local *preference* compared to older groups (as shown for the visual domain by Kimchi et al., 2005; Scherf et al., 2009; Scherf et al., 2008) which would be evident in their performance in the SENTCOMP task (Booth & Happé, 2010). Alternatively, it could be argued that providing local completions does not necessarily have to point towards a local processing style. It could also indicate less efficient inhibitory control so that the individual was not able to inhibit the first (local) response in order to give the more meaningful (global) response. Burgess and Shallice (1996), for example, used a sentence completion task in which frontal lobe lesion patients were asked to provide meaningful completions or such that did not fit the sentence context in order to examine inhibitory control. In the latter condition, inhibition of the more prevalent meaningful completion was necessary for a successful performance. Inhibitory control and the ability to suppress irrelevant information develops with age (Bedard et al., 2002; Lorsbach & Reimer, 1997; Williams, Ponesse, Schachar, Logan, & Tannock, 1999); thus, children could potentially be more affected by reduced inhibitory control in the SENTCOMP task.

Inhibition together with working memory and cognitive flexibility (also called set shifting) are the three core functions of executive control (or executive function, EF). The term inhibition encompasses inhibitory control, behavioural inhibition, interference control, i.e. selective attention and cognitive inhibition (Diamond, 2013; Moriguchi, Chevalier, & Zelazo, 2016). It also includes the suppression of irrelevant meanings (e.g. in the context of ambiguous words) or suppression of the first response that comes to mind (e.g. in SENTCOMP). Working memory (WM) is required to hold information active and to relate to it, for example, like in AMBSENT, where a sentence needs to be held in WM until the related/unrelated picture appears and a response can be given; or like in SENTORD, where mixed-up sentences need to be read, held in WM, and ordered to a meaningful story. Cognitive flexibility builds upon the other functions and involves shifting attention, for example, between processing levels in the hierarchical figures task (Chapter 8; see review by Pellicano, 2012, for more examples of cognitive flexibility tasks). Thus, those three executive functions seem critical for a successful and efficient performance on tasks like the ones applied in this research; One might even argue that EF are necessary for successful completion of any experimental task and even more so in everyday life: they are crucial for any goal-directed behaviour and the social-emotional and cognitive development of the individual (Moriguchi et al., 2016), as from those three core functions higher-order functions are developed which include problem-solving, reasoning, and planning (Diamond, 2013).

Booth and Happé (2010) examined whether a more local processing style in language might be due to reduced inhibition. They asked participants with ASD and ADHD to complete the SENTCOMP task as well as a go/no-go task measuring inhibitory control in which participants had to respond when they saw aeroplanes on the screen but withhold a response when they saw a bomb. The authors found that performance on both tasks was not related to each other. The ADHD group showed more inhibition problems than ASD but did not provide more local completions. Booth and Happe concluded that performance on SENTCOMP was not related to inhibitory control. Similar findings have been reported by Teunisse, Cools, van Spaendonck, Aerts, and Berger (2001) who examined central coherence and shifting abilities in TD and ASD.

Equivalent to the VISTA study, one aim of the current LANTA study was to establish developmental trajectories for LGLP in TD in tasks with increasing 'globality'. In a second step, those normative trajectories were compared to the performance of individuals with ASD (Section 9.2), in order to gain a better understanding of LGLP in this clinical group and potentially finding evidence for a developmental delay or qualitative different development in ASD.

Thus, the overarching aim for this Section 9.1 was to determine what the norm regarding LGLP for typical development is. Given this aim, the following questions were addressed based on the data from the four language tasks, i.e. Ambiguous Words (AMBWORD), Ambiguous Sentences (AMBSENT), Sentence Ordering (SENTORD), and Sentence Completion (SENTCOMP):

- *AMBWORD: How efficient (RT/ACC) is local lexical semantic processing of ambiguous words in TD participants?*

  It was expected that all participants would perform relatively well on the task (regarding RT and accuracy). Children would generally respond slower and less accurate than the older groups due to the immaturity of the cognitive system. The difference between the subordinate and dominant conditions might be higher in children, as they struggle more with suppressing the irrelevant dominant and activating other alternative meanings.
- *AMBSENT: How much contextual processing (i.e. local coherence) do TD participants show when accepting or rejecting alternative meanings of ambiguous words?*

Norbury (2005) demonstrated that children and adolescents exhibit contextual facilitation as well as interference from irrelevant meanings. It was thus expected that all age groups would show these effects, but that the older age groups would show better contextual processing compared to children, which would be indicated by higher contextual facilitation scores and higher contextual suppression scores.

- *SENTORD: How well (RT/ACC) can TD participants arrange sentences based on global coherence compared to when temporal (local) cues are available?*

  Jolliffe and Baron-Cohen (2000) assessed TD adults with this task and found no differences between the temporal and coherence conditions regarding accuracy; however, participants required less time to order sentences in the temporal condition than in the coherence condition. We would expect to replicate this finding with the current adult sample. Compared to older groups, RTs in children were expected to be higher, and accuracy lower. No predictions were made about differences between conditions regarding RTs and accuracy in children.

- *SENTCOMP: How prevalent are local and global language processing styles in TD?*

  It was expected that the majority of participants would show a global processing preference and give mainly, if not exclusively global completions (as in Booth & Happe, 2010). There would be some participants though, that would exhibit tendencies towards a local processing preference which would be apparent in an increased number of local completions.

### 9.1.2 Method

#### 9.1.2.1 Subjects

The same 68 participants aged 7 to 52 (*M* = 17.40, *SD* = 9.7) as described in Section 8.2.2.1 took part in this study as part of the wider language and perception study. Please see Table 8.1 on page 141 for a more detailed sample description. The task SENTCOMP was completed only by 16 participants (3 children, 3 adolescents, 10 adults) as it was introduced at a later stage of the data collection period.

#### 9.1.2.2 Tasks

Four language tasks were used in this study: Ambiguous Words (AMBWORD, 1 block) Ambiguous Sentences, (AMBSENT, 2 blocks), Sentence Ordering (SENTORD, 4 blocks), and Sentence Completion (SENTCOMP, 1 block). For a detailed description of the tasks please see the general methods (Section 6.5).

#### 9.1.2.3 Procedure

Participants completed the language tasks in the first assessment session of the larger language and perception study with alternating blocks of SENTORD, AMBWORD and AMBSENT. In the second assessment session, participants completed the task SENTCOMP (as well as the WASI and visual tasks), and a VOCAB-CHECK (see full description of the procedure and tasks in Section 6.5). If a participant did not know both meanings of a specific ambiguous word in VOCAB-CHECK, this word was excluded in the analysis for that individual (in AMBWORD and AMBSENT).

The results will be reported in separate sections for each experimental task/research question. Statistical results (ANOVA and post-hoc tests) and descriptive tables can be found in Appendix H. In text, only *p*-values of significant main effects or interactions will be provided.

### 9.1.3 AMBWORD: Local lexical semantic processing of ambiguous words in TD participants

Participants were auditorily presented with recorded ambiguous words (e.g. BALL), followed by a coloured picture of either one of the two meanings (dominant or subordinate meaning) of that word, or a neutral, i.e. not semantically related picture. Participants were asked to indicate with button press whether the picture could represent the meaning of the word or not. Ratios for RTs and accuracy of responses to dominant and subordinate meanings provided measures for dominant advantage or the discrepancy between processing of dominant and subordinate meanings in every participant ($DAS_{RT}$, $DAS_{ACC}$). AMBWORD was classed as a local processing task as it required semantic processing of single words. It was expected for TD and ASD to perform well in this task.

Please see Section 6.5.2 in the General Methods section for a full description of the task.

### 9.1.3.1 Analysis

For RT and accuracy separately, 3x3 repeated measures ANOVAs were calculated with the factors picture type (dominant meaning, subordinate meaning, neutral) and age group (child, adolescent, adult). For significant interactions or main effects, Bonferroni correct post-hoc tests/pairwise comparisons were conducted.

Further, dominant advantage scores (DAS, see formulas in Appendix A) for RT and accuracy were calculated in order to assess advantage of processing of dominant meanings compared to subordinate meanings. Values of 1 indicate no advantage (dominant = subordinate). The higher the values, the more dominant advantage the participants showed. Age effects in the DASs were examined by means of one-way ANOVAs. The $DAS_{RT}$ and $DAS_{ACC}$ were also averaged to one $DAS_{total}$ score and compared between groups.

Descriptives can be found in Table H.37 in Appendix H.1 and statistical results in Table H.38 (ANOVA) and Table H.39 (post-hoc tests).

### 9.1.3.1 Results

No speed-accuracy trade-off was found overall or in any age group or condition ($p > .05$).

The ANOVAs examining the effect of picture type and age group on RT and accuracy both showed significant main effects of type and of age group (all $p < .001$). Further, in accuracy the interaction Type x Age Group was significant ($p = .001$).

The analyses showed that overall, children had the slowest RTs and lowest accuracy, whereas adolescents and adults did not differ (cf. Figure 9.1). RTs to dominant meanings were fastest, followed by neutral and then subordinate meanings. Pairwise comparisons showed that accuracy was comparable for dominant and neutral pictures ($p = .478$), and higher in dominant than subordinate pictures ($p < .001$); however, only in children responses were more accurate to neutral pictures than to those of subordinate meanings ($p < .001$).

The analysis of the $DAS_{RT}$ showed that all age group benefited comparably from dominance and responded faster to dominant meanings than subordinate meanings (n.s. main effect of age group: $p$ = .148, Kruskal-Wallis Test $p$ = .059). In terms of accuracy, children benefitted more from meaning dominance than adolescents or adults did (sig. effect of age group on $DAS_{ACC}$: $p$ = .001, the same was true for $DAS_{total}$: $p$ = .003), indicating that in younger participants either the representation of the subordinate meaning was not as present/active although they did know both meanings, and/or they failed to suppress fast negative responses ("no" to a picture with subordinate meaning), possibly because the dominant meaning was far more accessible than the subordinate meaning.

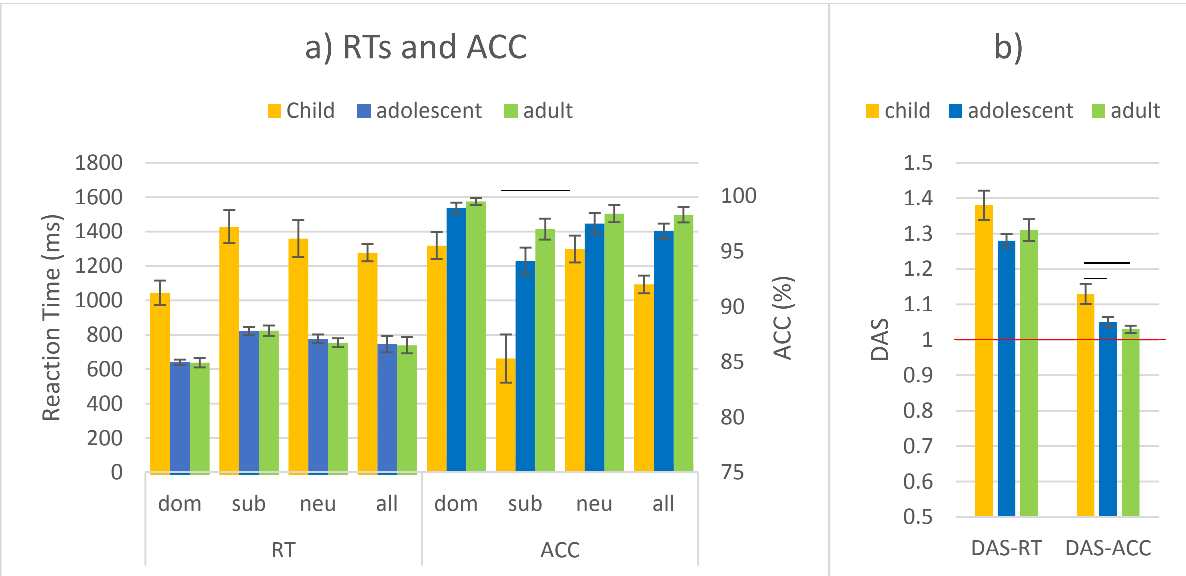



*Figure 9.1.* AMBWORD RT and accuracy data (a) as well as Dominant Advantage Score (DAS) in RT and accuracy (b).
dom: dominant, sub: subordinate, neu: neutral. Means and SE are displayed. Children had higher RTs and lower accuracy than the older groups. RTs for dom were lowest, followed by neu and sub. Children had lower accuracy in sub compared to neu and a higher $DAS_{ACC}$ compared to the other age groups. The red line at DAS = 1 represents no dominant advantage. ─ indicate significant differences.

### 9.1.3.2 Summary and Discussion

Overall, as expected, the analysis of semantic processing efficiency showed that adolescents performed comparably to adults, while children showed less efficient performance regarding RTs and accuracy. All groups showed an advantage when responding to dominant pictures, but the child groups struggled relatively more with subordinate pictures. This was also reflected in the DAS ($DAS_{ACC}$ and $DAS_{total}$) which was significantly higher in children than in adults.

AMBWORD represented a local processing task as it involved processing of single elements (words). It was predicted that all age groups would perform relatively well. The finding that children performed slightly worse compared to adults could indicate that the children had a reduced local processing ability or less efficient inhibitory control, in particular, weaker suppression of the dominant meaning or of hasty negative responses compared to the older participants.

### 9.1.4 AMBSENT: Local coherence or semantic processing of ambiguous words in sentence contexts in TD participants

In this task, participants were auditorily presented with short recorded sentences containing an ambiguous word, followed by a coloured picture of either the dominant or subordinate meaning of that word. There were 8 different sentence-picture combinations for each ambiguous word. Sentences could either be biased towards one of the meanings (e.g. She played with/met him at the ball → suitable picture of toy ball/dance ball), be neutral (She wanted a ball → either picture) or unambiguous (She played with a doll / met him on a conference → unsuitable pictures). In the *facilitation condition*, the context of the sentence facilitated (i.e. primed) acceptance of suitable pictures, whereas in the *suppression condition* the context helped to suppress irrelevant meanings and therefore reject the unsuitable picture. Please see Section 6.5.3 in the General Methods section for a full description of the task and Table 6.1 on page 100 for a more detailed overview of the conditions.

#### 9.1.4.1 Analysis

The data from AMBSENT was analysed in two separate analyses (equivalent to Norbury, 2005), one for contextual facilitation, one for suppression, and separately for RTs and accuracy. For the facilitation condition, 2x2x3 repeated measures ANOVAs with within-subjects factors context type (biased, neutral) and dominance (dominant, subordinate) and the between subjects factor age group (child, adolescent, adult) were calculated for the DV RT and for accuracy. For the suppression condition, the within-subjects factor context was replaced with the factor ambiguity (ambiguous, unambiguous). Otherwise, the analyses were equivalent between both conditions.

Additionally to the ANOVAs, Contextual Facilitation Ratios (CFR, separately for RT and accuracy and for subordinate and dominant meanings; see Appendix A for formulas for the CFR and all following indicators) were calculated, indicating the facilitation through context when accepting meanings for ambiguous words (the higher the CFR, the more participants benefited from the contextual information). Further, Contextual Suppression Ratios (CSR, again for RT, accuracy, dominant and subordinate) were calculated, indicating the benefit of context in order to suppress and reject irrelevant meanings (the higher the CSR, the more benefit from contextual information). Two 2 (dominance) x 3 (age group) repeated measures ANOVAs were used to analyse the data.

Norbury (2005) calculated a Total Facilitation Score (N-TFS) was the difference between RTs or accuracy in biased vs unbiased sentences. As it depended on the total RT or accuracy of the participants, children were likely to have higher TFS due to generally responding slower/less accurate. Therefore, instead of Norbury's Facilitation Scores, Total Facilitation Ratios (TFR) were calculated for RTs and accuracy with TFR equal to 1 indicating no facilitation and higher TFRs indicating more facilitation. Further, a Total Interference Score (TIS, combined for dominant and subordinate, separate for RT and ACC) was calculated indicating the amount of contextual interference participants experienced with scores equal to 0 showing no interference and larger scores indicating higher interference from irrelevant meanings of the ambiguous words. Although Norbury (2005) provided values for the $TIS_{ACC}$, she did not provide a formula. It was thus deducted from the $TIS_{RT}$.

One-way ANOVAs were used to assess differences in the N-TFSs, TFRs and TISs between age groups.

In Appendix H.2, descriptives can be found in Table *H.41* and inferential results in Table *H.43*, Table *H.44* (ANOVAS), and Table *H.45* (post-hoc tests).

#### 9.1.4.2 Results

No speed-accuracy trade-off was found overall or in any age group or condition ($p > .05$).

Overall, children gave the slowest responses followed by adolescents and adults who did not differ. Children also showed the least accuracy followed by adolescents and adults (all main effects of age group: $p \leq .001$). See Figure 9.2 and Figure 9.3 for a visualisation of the RT and accuracy data in each age group and condition.

#### *9.1.4.2.1 Facilitation Condition*

In the RT analyses of the *Facilitation Condition*, the ANOVA revealed significant main effects of context, dominance and age group (all $p < .001$) while there were no significant interactions. Responses to dominant meanings were faster than to subordinate meanings and faster to biased pictures than to unbiased/neutral pictures (all $p < .001$). No interactions with age were found, indicating similar patterns across development. This was also supported by no age effects regarding the N-$TFS_{RT}$ and $TFR_{RT}$ (both $p > .05$) The $CFR_{RT}$ analysis showed that all age groups benefitted more from bias in the subordinate condition than in the dominant condition (main effect of dominance: $p = .048$).

The ANOVA for accuracy in the *Facilitation Condition* revealed the significant interactions Context x Dominance x Age Group ($p = .021$), Context x Dominance ($p < .001$), Dominance x Age Group ($p < .001$), as well as main effects of context, dominance and age group (all $p < .001$). The difference in accuracy between dominant and subordinate conditions decreased with age: participants became better with age in correctly identifying subordinate meanings (compare Figure 9.2). This was also supported by the $CFR_{ACC}$ results where a significant interaction of Dominance x Age Group was found ($p = .001$): there were similar $CFR_{ACC}$ across ages in the dominant condition ($p = .769$) but reduced $CFR_{ACC}$ (i.e. less benefit by biasing meanings) in the subordinate condition with higher age (child vs adolescents; $p = .010$; child vs adult $p = .005$; However, the nonparametric Kruskal-Wallis Test did not show an effect of age group, $p = .402$). The $TFR_{ACC}$ which indicates facilitation across both subordinate and dominant conditions (and is therefore less specific than the CFR) did not show any age effects ($p > .05$). Further, when the CFR and TFR were analysed for significance, i.e. whether they differed significantly from 1 (1 = no facilitation), the $CFR_{ACC}$ for dominant meanings was not significant, indicating no significant contextual facilitation for dominant meanings in any age group, while other indicators were all significant.


*Figure 9.2.* a) RT data, b) accuracy data, c) CFR and d) TFR in the facilitation condition in the task AMBSENT for TD.
Dom: dominant; sub: subordinate; bias: biasing context; neu: neutral context. RTs to dom were faster than to sub and RTs to bias were faster than neu. In accuracy the difference between sub and dom decreased with age. CFR-RT and CFR-ACC were higher than dom. CFR-ACC decreased with age.

#### *9.1.4.2.2 Suppression Condition*

In the RT analyses of the *Suppression Condition,* the ANOVA revealed significant interaction of Ambiguity x Dominance ($p$ = .008) as well as significant main effects of ambiguity ($p$ = .003), dominance ($p$ < .001), and age group ($p$ < .001). RTs between the unambiguous and ambiguous sentences did not differ in the dominant conditions ($p$ > .05), but they were lower in unambiguous than ambiguous sentences in the subordinate condition (compare *Figure 9.3*a). In the $CSR_{RT}$, a measure for how well participants used context to suppress irrelevant information, the ANOVA showed a significant main effect of dominance ($p$ = .014), but not age group ($p$ = .671). The $CSR_{RT}$ was higher in the dominant ($M$ = .99) than in the subordinate condition ($M$ = .93, $p$ = .014), indicating that context was of more benefit for suppression of irrelevant meanings when it was priming towards a dominant meaning than a subordinate meaning, although overall the RTs in the dominant condition were higher than in the subordinate one. No age effects were found in the $CSR_{RT}$ or the $TIS_{RT}$ ($p$ > .05). However, when the CSR and TIS were analysed for significance (CSR ≠ 1, TIS ≠ 0), the $CSR_{RT}$ was not significantly different from 1 in any age group, while the $TIS_{RT}$ was only significant in children, indicating no significant interference in older participants.


*Figure 9.3.* a) RT data, b) accuracy data c) CSR, d) TIS in the suppression condition in the task AMBSENT for TD.
Dom = dominant; sub = subordinate; amb = ambiguous; unamb = unambiguous. For RT, amb and unamb differed for sub, but not dom meanings. For accuracy, ─ indicate significant differences. CSR-RT and CSR-ACC were higher for dom than sub. The CSR-ACC and TIS-ACC were higher in children than in adults.

The ANOVA with the DV accuracy in the *Suppression Condition* showed a significant interaction of Ambiguity x Dominance ($p$ = .003; however, all pairwise comparisons were significant $p \leq .035$) and Ambiguity x Age Group ($p$ = .010; only ambiguous trials did not differ between adolescents and adults ($p > .05$), but all other groups), as well as significant main effects of ambiguity ($p < .001$) and age group ($p$ = .001). Accuracy was higher in unambiguous trials than in ambiguous ones (Figure 9.3b).

The $CSR_{ACC}$ ANOVA revealed a significant effect of dominance ($p$ = .004) and age group ($p$ = .009). The $CSR_{ACC}$ was higher in the dominant ($M$ = .89) than the subordinate condition ($M$ = .84, $p$ = .004). It was further lower in children ($M$ = .80) than adults ($M$ = .92, $p$ = .008) indicating less contextual suppression in children, but not significantly lower in children than adolescents ($M$ = .88, $p$ = .128). Accordingly, the $TIS_{ACC}$ (higher scores indicate more contextual interference) showed that children had a higher interference from irrelevant meanings ($M$ = .21) than adults ($M$ = .08, $p$ = .008) but not adolescents ($M$ = .12; $p$ = .877, main effect of age group: $p$ = .009).

#### 9.1.4.3 Summary and Discussion

This section examined how much contextual processing (i.e. local coherence) TD participants showed when accepting or rejecting dominant or subordinate meanings of ambiguous words.

The results showed that in the facilitation condition participants responded quicker to dominant meanings but benefitted more from context when it biased the subordinate meaning. Similarly, context was of slightly more benefit (regarding accuracy) for suppression of irrelevant meanings when it was biasing towards the subordinate meaning (e.g. S*he met him on a ball* vs. *She met him at a conference* followed by *toy ball picture*) compared to when it biased towards the dominant meaning (*She played with a ball* vs. *she played with a doll* followed by *dance ball picture*).

Participant’s ability to respond correctly to subordinate meanings with or without biasing context improved with age which was equivalent to the AMBWORD results. Further, children’s contextual facilitation was comparable to adults in the regards to dominant meanings, but they benefitted relatively more from context for the subordinate meaning. However, this effect was not significant in a non-parametric test; thus, the significant difference in the parametric test was mainly due to outliers in the child group. Further, Chapman, Chapman, Curran, and Miller (1994) demonstrated that such difference scores (as here the CFR) can easily lead to paradox findings, in this case, better context use in children; however, this is simply because children showed generally reduced accuracy and there was, therefore, more scope for improvement through context use (compare Figure 9.2b). Fittingly, there was a significant correlation in children between accuracy in the facilitation condition and the $TFR_{ACC}$ ($r$ = -.639, $p$ = .002) indicating that worse performance regarding accuracy was associated with higher facilitation scores. This explains why the prediction of better contextual facilitation in older participants was not met.

In terms of interference, there was no significant difference between accuracy to dominant ambiguous (*She played with a ball)* and unambiguous sentences (*She played with a doll* followed by *dance ball picture*) in adults, indicating most efficient use of sentence context and least interference from irrelevant meanings in that age and condition, compared to other ages or the subordinate condition. Interestingly, although some children's accuracy benefitted more from context to activate the appropriate meaning ($CFR_{ACC}$), the suppression of irrelevant meanings was significantly reduced in children ($CSR_{ACC}$). This also led to higher interference from irrelevant meanings (TIS) in children who were the only age group with a significant TIS. Both indicators (CSR, TIS) showed children were less efficient in using the context sentence to suppress the inappropriate meaning which was in accordance with our prediction. Together the results show that the ability to suppress irrelevant information develops with age (cf. Bedard et al., 2002; Lorsbach & Reimer, 1997; Williams et al., 1999).

Norbury (2005) had hypothesised (based on Gernsbacher & Faust, 1991; Merrill, Sperber, & McCauley, 1981) that TD children would not show interference if the picture was presented with a 1 second delay after the sentence, as by this point (after an initial activation of both meanings) only the correct meaning of the word would be active. However, like in the current study, Norbury also found significant interference effects in their TD sample and attributed those findings to the different type of task compared to the other authors. Gernsbacher and Faust (1991) sample consisted of adult participants (skilled comprehenders); thus our findings are partly consistent with their results as the current adolescent and adults samples did not show significant interference regarding RTs. Thus, children appear to need more time for the deactivation of the irrelevant meaning of ambiguous words. Future investigations could try to establish at what inter-stimulus intervals children do not experience interference from irrelevant meanings.

In the introduction, it was argued that performance on this task could be influenced by central coherence (CC) and/or EF. One might argue if CC and EF were to be distinguished, that the use of context in order to facilitate relevant meanings is more a facet of CC (or in this case local coherence), whereas contextual suppression belongs more to EF (inhibitory control, although local coherence is also involved). Our finding would then suggest that children showed good CC but reduced EF. However, an alternative interpretation would also be possible: In the facilitation condition, performance could rely on a simple picture verification task (e.g. She met him at a BALL → dance ball picture → "yes this is a ball" → correct). In this case, sentence context could be mostly neglected and only the main object taken into account, and performance would still be fairly good, as the answer would always be a yes. All errors would then be due to careless mistakes or hasty responses, thus more related to EF than CC. In the ambiguous sentences of the suppression condition, the meaning of BALL is more constraint by the sentence and a yes would be incorrect (e.g. She met him at a BALL → toy ball picture → "yes this is a ball" → incorrect). Thus, increased use of context is necessary in order to perform accurately, thus contextual suppression would rely to a larger extent on CC. As apparent from the two opposing explanations, a distinction whether performance relies on CC or EF is not possible based on the current data. If a separate EF task, e.g. a go/no-go task had been included in the assessments (e.g. like in Booth & Happe 2010), a correlation analysis between this task and AMBSENT might have clarified the involvement of EF in the performance in AMBSENT.

To summarise the current findings: the analysis of the local coherence task AMBSENT revealed that children were able to use context efficiently to activate relevant meanings, but they were less efficient in the suppression of irrelevant meanings. In how far performance in contextual facilitation and suppression relied on CC or EF remained open.

### 9.1.5 SENTORD: Global coherence vs local cues in TD participants

In this task, participants were presented with 5 sentences and a title on separate cards belonging to a story. They were asked to order the sentences so that "the story makes sense". In the *coherence condition* (8 stories), participants had to use global coherence/global processing of the whole story in order to successfully order the sentences. In the *temporal condition* (8 stories), temporal cues were given which aided ordering (In the morning, in the afternoon, later etc.), so that successful completion of this condition was possible by relying on those (local) cues and neglecting the overall sentences or story content. Please see 6.5.4 in the General Methods section for a full description of the task.

#### 9.1.5.1 Analysis

RT data were log-transformed (base 10) in order to achieve normality and homogeneity of variances between groups (equivalent to Jolliffe & Baron-Cohen, 2000).

Two 2x3 repeated measures ANOVAs with the within-subjects factor condition (coherence, temporal) and the between-subjects factor age group (child, adolescent, adult) were calculated for the DVs RT and accuracy. Significant effects were further explored with Bonferroni-corrected post-hoc tests.

Temporal facilitation ratios (TempFR, see Appendix A for the formula) were calculated for each DV. TempFR equal to 1 indicated RT (or accuracy) were the same in both coherence and temporal conditions. TempFR greater than 1 indicated participants were aided by the temporal cues in the temporal condition. TempFR less than 1 indicated that temporal cues did not benefit (but indeed impaired) performance leading to higher RT / lower accuracy. Univariate ANOVAs were used to compare TempFR s between age groups.

Descriptive data can be found in Appendix H.3.1, Table H.48, and inferential results can be reviewed in Appendix H.3.2, Table H.49 (ANOVA) and Table H.50 (post-hoc tests).

#### 9.1.5.2 Results

No speed-accuracy trade-off was found overall or in any age group or condition ($p > .05$).

#### 9.1.5.2.1 Reaction Times

The 2x3 repeated measures ANOVA with factors condition and age group revealed only a significant effect of age group ($p = .001$). Bonferroni post-hoc tests revealed that children had significantly higher RTs than adolescents but not adults, whereas adolescents were also faster than adults. There was no difference in RTs between the temporal and coherence condition (Figure 9.4a).

No age group effect was found in the $TempFR_{RT}$ analysis. The $TempFR_{RT}$ was not significantly different from 1 in any age group ($p > .52$ in one-sample t-tests), showing that in the TD sample, no facilitation through temporal cues occurred (based on RT data).

#### 9.1.5.2.2 Accuracy

The ANOVA of accuracy revealed significant age group differences ($p < .001$) and significant differences between accuracy in the temporal and coherence conditions ($p = .001$). Post-hoc tests showed that children had lower accuracy scores than adolescents and adults, whereas the groups of adolescents and adults did not differ. Accuracy in the coherence condition was lower than in the temporal condition (Figure 9.4b).

The $TempFR_{ACC}$ showed no significant age group effects. However, the $TempFR_{ACC}$ was significantly different from 1 only in adults ($p = .002$), showing facilitation through temporal cues in this age group, but not in the other two age groups (Figure 9.4).

### 9.1.5.3 Summary and Discussion

The analyses comparing RTs and accuracy between the coherence and temporal conditions showed no significant differences, although as predicted, children had the highest RTs and lowest accuracy overall. However, in the TempFR analysis, adults were the only age group that showed a significant benefit on accuracy in the temporal cue condition, which could indicate better local processing skills with older age. Although it was expected based on Jolliffe and Baron-Cohen (2000) to find lower RTs in the temporal condition compared to the coherence condition, this was not found.

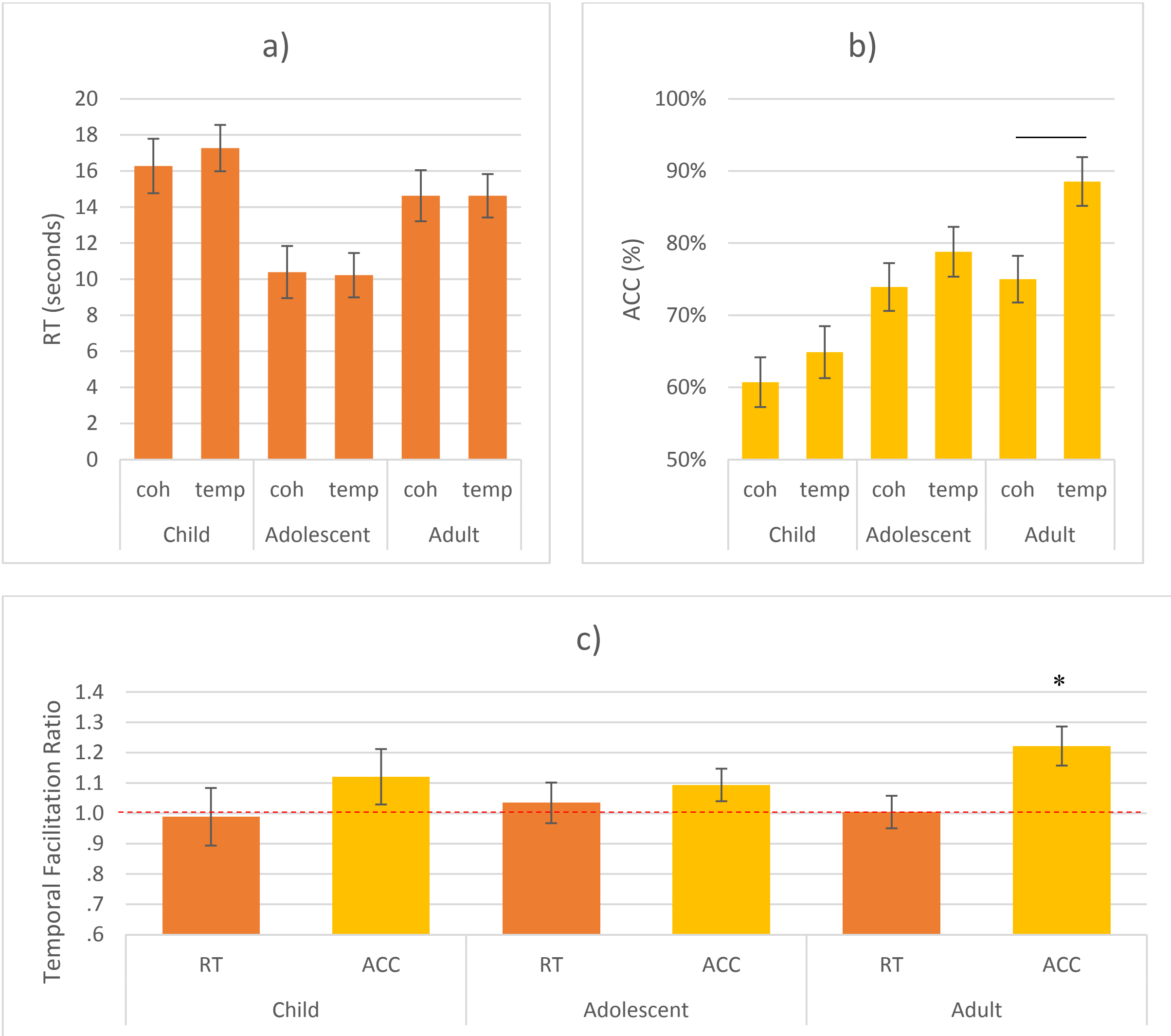



*Figure 9.4.* a) RT, b) accuracy data, c) Temporal Facilitation Ratio in the task SENTORD. TempFR > 1: temporal facilitation. TempFR = 1: no facilitation. For TempFR * indicates a significant difference from 1. — indicate significant difference between conditions. Error bars are standard errors.

To summarise, overall, the current TD sample did not show large differences in performance in ordering sentences based on global coherence or temporal cues. Performance regarding RTs and accuracy improved with age; however, only in the adult group, accuracy was higher in the temporal than coherence condition. This supports the idea that local and global processing lie on two separate continuums and develop alongside each other (Happe & Booth, 2008).

### 9.1.6 SENTCOMP: Language processing styles in TD

In this task, participants were presented with incomplete sentences that were likely to elicit either global or local sentence completions depending on whether the whole (global) sentence was taken into account or just the last (local) words, e.g. "He went hunting with a knife and…" (a global completion would be "gun", whereas a local completion would be "fork"). The task did not differentiate between poor global processing (of the whole sentence) or enhanced local processing (of only the lasts words), but represents more the (automatic) processing preference of the individual. A total completion score (CS), the number of local completions (LC) and completion time (RT) were calculated from 10 experimental trials. The higher the CS and lower LC, the more global processing did the participant exhibit. Please see Section 6.5.5 in the General Methods for a full description of the task which was the same as in Booth and Happe (2010).

#### 9.1.6.1 Analysis

The Sentence Completion task was only completed by 3 TD children, 3 TD adolescents and 10 TD adults, as it was introduced at a later stage of data collection. The reported results are therefore only indicative of this small sample (see Table 9.1 for descriptive results). However, Booth and Happe (2010; and Booth, 2006, in her dissertation) provided normative TD data for males and females aged between 8 and 25 years that can be used for a comparison to the current TD (cTD) as well as ASD data.

Z-scores for the completion score (CS), number of local completions (LC) and RT (RT) were calculated for the current sample (cTD) based on Booth and Happe's TD sample (BH TD, see Table 9.2).

Table 9.1

*Descriptive Results (M, SD) per age group in SENTCOMP*

| | Child<br>N = 3 | Adolescent<br>N = 3 | Adult<br>N = 10 |
|---|---|---|---|
| Completion Score (max = 20) | 16.33 (3.79) | 18.33 (2.89) | 18.50 (2.37) |
| Range | 12-19 | 15-20 | 12-20 |
| Number of local completions (maximum = 10) | 1.00 (1.73) | .67 (1.15) | .40 (.97) |
| Range | 0-3 | 0-2 | 0-3 |
| RT to test stems (s) | 5.12 (.43) | 2.37 (.56) | 3.45 (1.68) |
| Range | 4.65-5.50 | 1.95-3.00 | 1.05-6.15 |

Table 9.2

*Comparisons of current TD data and the TD data from Booth & Happe's (2010) study (SENTCOMP task)*

| | Child | | Adolescent | | Adult | |
|---|---|---|---|---|---|---|
| | *z*-score | *p*-value | *z*-score | *p*-value | *z*-score | *p*-value |
| cTD vs BH TD | | | | | | |
| Completion Score | -0.514 | 0.184 | -0.110 | 0.456 | -0.013 | 0.496 |
| Local Completions | 0.257 | 0.101 | 0.112 | 0.456 | -0.124 | 0.452 |
| RT | 3.268 | 0.001 | 1.399 | 0.082 | 1.526 | 0.064 |

*Note.* cTD = current TD participants ($N = 16$), BH TD: Booth & Happe's (2010) participants ($N = 136$).

### 9.1.6.2 Results and Discussion

The data from this small sample of participants showed that overall, CS were high and number of LC low in all age groups which was in accordance with our expectations. The comparison with between cTD and BH TD showed that there was no significant difference between the cTD and BH TD except in children: RTs in the current child sample were higher than in BH TD. In general, however, the cTD and BH TD samples performed similarly. This allowed for the BH TD sample to be used as a comparison to the current ASD sample instead of the current (limited) TD sample (in Section 9.2.6).

Booth and Happe (2010) concluded from their TD data that individual differences in performance were independent of IQ. Further, they found age group differences in the CS only in males (younger participants scored lower than older participants) but not the other measures or in females. Regarding RTs, results were similar to the present sample, in that children had the slowest RT, followed by adults, while adolescents (in Booth's study the 14-16-year-olds) gave the fastest responses.

However, in contrast to Booth and Happe, a significant positive correlation was found in our adult sample between the WASI VP score (but not the NVP or FSIQ) and the completion score ($rho = .646$, $p = .044$) as well as VP and the RT ($rho = -.782$, $p = .008$). The correlation between VP and number of local completions (LC) was not significant ($rho = -.237$, $p = .509$), indicating that lower verbal skills (i.e. vocabulary) were associated with slower but not more local responses in SENTCOMP. Note, however, that the current adult sample size is very small with $n = 10$. No correlations were calculated for children or adults due to the extremely low sample sizes.

Due to the small sample size, no statements can be made regarding the developmental trajectory in TD based on our sample. In Booth and Happe's (2010) study, the CS increased with age in males (with 8 to 13-year-olds having a lower score than 14 to 25-year-olds) but not in females, which indicates a more local processing style in younger males than older ones. However, the number of LC did not differ between age groups.

Booth (2006) categorised participants as displaying weak central coherence (or a local processing style) if they provided two or more local completions. This criterion applied to 1 out of 3 children (33%, age 7-11), 1 out of 3 adolescents (33%, age 12-17), and 1 out of 10 adults (10%, age 18+) in the cTD sample (see also Section 9.2.6). Booth (2006) had found a local style in 17% participants from the child group (age 8-10), 17% in adolescents (aged 11-16), and 10% in adults (age 17+).

Importantly, Booth and Happe (2010) also applied a measure for impulsivity (go/no-go task) in order to test the assumption that increased local completions were due to impulsive responses, and thus reduced inhibitory control; however, they found no correlations between this task and SENTCOMP performance. They also did not find significantly more local completion in a sample with ADHD compared to ASD. Based on those results, SENTCOMP appeared to be indeed a suitable task to measure cognitive styles in language.

### 9.1.7 Summary and Conclusion

Following, the results of this section will be summarised to give an overview of local and global language processing in TD before comparing it to processing in ASD in the next Section 9.2.

In AMBWORD (a local task), children had a higher dominant advantage which was shown in more false negative responses to pictures representing the subordinate meanings of ambiguous words compared to those representing the dominant meaning. This could indicate either less successful suppression of the dominant meanings or less successful inhibitory control of impulsive responses in this age group.

In AMBSENT (a local coherence task), all participants showed a dominant advantage by responding quicker to dominant meanings than subordinate meanings. They benefitted more from sentence context when the sentence was biased towards the subordinate meaning. Children experienced significant interference from irrelevant meanings (i.e. less contextual suppression) which could stem from not considering the sentence context but only matching the picture to last words. This was in contrast to the older age groups who did not show notable interference scores. Furthermore, it was found that adults had the most efficient use of sentence context (local coherence) and the least interference from contextually inappropriate meanings. In brief, suppression ability improved with age (Bedard et al., 2002; Lorsbach & Reimer, 1997; Williams et al., 1999) as did local coherence.

In SENTORD, no differences were found regarding accuracy and RT between the coherence and temporal conditions overall, although general performance (in both, temporal and coherence condition) improved with age. Further, adults demonstrated significant temporal facilitation, indicating that use of local cues was best in this age group compared to the younger groups. This supports the notion that local and global processing develop alongside each other, and that the ability to select the most appropriate processing level (and switch between them) improves with age. This has previously been suggested by other researchers (Evans et al., 2013; Happe & Booth, 2008; Happe & Frith, 2006; Huizinga et al., 2010; Pletzer et al., 2017).

The comparisons of the current small dataset in SENTCOMP to Booth and Happe's (2010) larger study showed that result patterns were mostly similar. In contrast to Booth and Happe, however, we found a significant correlation in the adult participants between VP and CS, VP and RT, but not VP and LC. Thus, verbal skills had a positive impact on response speed in our participants (which affected the CS) but did not influence whether local or global completions were given. Although Booth and Happe (2010) and Booth (2006) did not find differences in the number of LC between age groups, Booth (2006) showed that the percentage of individuals in each age group showing a local processing style (i.e.two or more LC) generally reduced with age. Ten per cent of their adult sample had a local processing style which was equivalent to what was found in the current adult sample (1/10 participants). Lastly, Booth and Happe (2010) did not find a relationship between the CS and a measure for inhibitory control, indicating that a more local response pattern was not due to impulsive responses but in fact represented a local processing style in their participants. However, as will be discussed later in this chapter (Sections 9.2.6 and 9.3), we would argue that there might be involvement of an EF component after all.

In Chapter 2, four combinations of possible LGP abilities were presented (based on Happe and Frith, 2006): A: weak global and strong local abilities; B: strong global and strong local abilities; C: weak global and weak local abilities; D: strong global and weak local abilities (Figure 9.5). It appears that for the majority of TD individuals the development is from C (relatively) weak global and local abilities in childhood to B strong local and global abilities in adulthood. Nevertheless, there are interindividual as well as task-dependent differences.

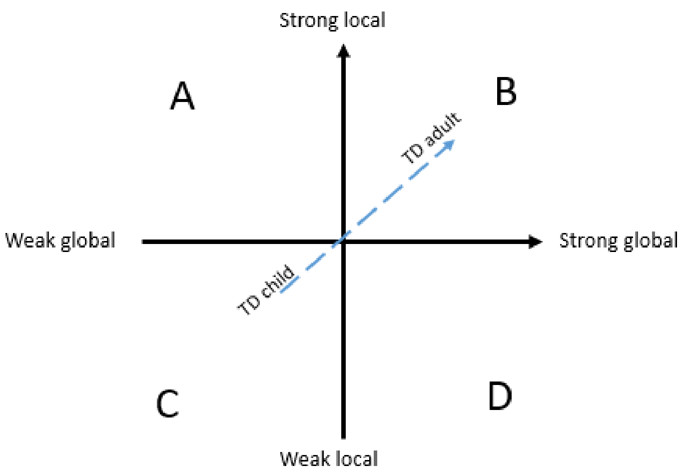



*Figure 9.5.* Local and global processing in a two-dimensional space from weak to strong local and global processing with a suggested developmental trend in TD.

## 9.2 Local and global language processing in ASD

### 9.2.1 Introduction

The results in the previous Section 9.1 showed that in TD, performance on local, local coherence, and global coherence tasks improved with age. This was found regarding general RTs and accuracy, but also more specifically regarding the use of contextual information for suppression of irrelevant meanings. In this next section, a sample of 50 participants with ASD was be compared to an age-matched selection of those TD participants. The overarching question in this section was whether and how LGLP in ASD differed from processing in TD and whether their performance reflects a developmental delay or qualitatively different development. In view of this question, the ASD participants were asked to complete the same four language tasks as described in Section 9.1.

It was expected to find comparable performance to TD in the task AMBWORD, although the ASD group might show slightly higher dominant advantage (Norbury, 2005), potentially with higher accuracy in the dominant condition compared to TD but lower accuracy in the subordinate condition.

In AMBSENT, results between TD and ASD were also predicted to be similar, although there could have been a tendency for less interference in the ASD group and better use of context in order to suppress irrelevant meanings (as found in Norbury's ASD group without language impairment (LI), although the difference was not significant).

The TD and ASD groups were expected to differ in SENTORD, with ASD showing higher temporal facilitation than TD (i.e. faster/more accurate responses in the temporal condition compared to the coherence condition) but reduced accuracy in the coherence condition compared to TD due to enhanced local processing abilities (based on Jolliffe & Baron-Cohen, 2000).

In SENTCOMP, it was expected that more participants with ASD would show a local processing style with lower CS and higher numbers of LC compared to TD (Booth & Happe, 2010).

### 9.2.2 Method

#### 9.2.2.1 Subjects

Fifty participants with ASD aged 8 to 54 ($M$ = 22.54, $SD$ = 14.84) took part in the experiments. They were the same as in the VISTA study and are described in Section 8.2.2.1. Please see Table 8.7 on page 168 for the sample characteristics. Only 43 ASD participants completed the experiment SENTCOMP as it was introduced at a later stage of the data collection period.

The ASD participants were compared to an age-matched TD (AmTD) sample which consisted of 45 subjects form the overall TD sample. Descriptive information about the control sample can also be found in Section 8.2.2.1.

#### 9.2.2.2 Procedure

The procedure was the same as described in Section 9.1.2.3.

#### 9.2.2.3 Analysis

The analyses were performed equivalently to the analyses in TD (as described in the Subsections 9.1.3 to 9.1.6) but with the additional between-subjects factor sample group (AmTD vs ASD). The results will be reported in separate sections for each experimental task. The focus lied on the ASD data. Results that were independent of the sample group (i.e. no significant main effect or interaction with sample group) will not be reported in detail. Significant sample-specific effects were examined further. Detailed ANOVA results and descriptives can be found in the Appendix H.1.

Additionally to the group comparisons with ANOVAs, z-scores were calculated for certain variables for every participant based on the mean and standard deviation of the respective TD age group (total sample). Z-scores allow for a comparison of individual scores to the average population and indicate the distance a score lies from the mean in units of standard deviations. Z-scores with absolute values over 1.645 were interpreted as extreme scores or atypical (outside the 90% confidence interval). The percentage of individuals in each age and sample group with atypical performance (AP) was calculated and will be reported for AMBWORD, AMBSENT and SENTORD. Due to the TD missing data in SENTCOMP, a different approach was adopted: the participants were categorised into showing a local or global processing style and the results were compared to Booth and Happe's (2010) normative sample.

### 9.2.3 AMBWORD: Lexical Semantic processing of ambiguous words in ASD vs AmTD participants

Descriptives can be found in Table H.37 in Appendix H.1 and statistical results in Table *H.40*.

#### 9.2.3.1 Results and Discussion

The 3x3x2 ANOVA with the factors type (dominant, neutral, subordinate), age group (child, adolescent, adult) and sample group (AmTD, ASD) and the DV RT showed that the main effect of sample group influenced RTs significantly ($p$ = .002). Participants with ASD showed longer RTs ($M$ = 1085.48) than

TD participants (*M* = 929.11). No significant interactions with sample group were found (all $p > .05$). The ANOVA with the DV accuracy showed no significant main effect of or interactions with sample group (all $p > .05$). Similarly, the $DAS_{RT}$ and $DAS_{ACC}$ did not differ between samples. The AP analysis (

Table *9.3*) showed that the groups did not differ much regarding accuracy or DAS, but more than 1/3rd of ASD participants had high RTs.

Table 9.3

*Percentage of individuals in each age and sample group with atypical performance (z > 1.645) in AMBWORD*

| | TD | | | | ASD | | | |
|---|---|---|---|---|---|---|---|---|
| | child | adolescent | adult | total | child | adolescent | adult | total |
| higher RT | 10% | 9% | 8% | 9% | 17% | 50% | 40% | 38% |
| lower ACC | 10% | 4% | 8% | 7% | 8% | 6% | 10% | 8% |
| Higher $DAS_{total}$ | 5% | 0% | 4% | 3% | 0% | 6% | 0% | 2% |

*Note. The $DAS_{RT}$ and $DAS_{ACC}$ were combined to a total dominant advantage score $DAS_{total}$.The AmTD groups also vary on AP prevalence, as z-scores were derived from the total TD sample (n = 68).*

In sum, AmTD and ASD performed very similarly in regards to accuracy, but the ASD group had greater reaction latencies which was also consistent with the findings in the AP analysis. The percentage of AP in ASD increased from children to adolescents before dropping again in adults (the difference was, however, only one participant). This could indicate a developmental delay in the ASD groups compared to TD, i.e. both groups start similar as children but the ASD group develops slower.

The finding of reduced performance in ASD was surprising giving that AMBWORD was classed as a local task and thus, participants with ASD were expected to perform well, if not better than AmTD. The results might reflect higher cognitive demand in ASD, potentially due to more effortful suppression of the dominant meaning of the ambiguous words.

### 9.2.4 AMBSENT: Local coherence or semantic processing of ambiguous words in sentence contexts in ASD vs AmTD participants

The data from AMBSENT was analysed with ANOVAs as described in Section 9.1.4.1 but with the additional between-subjects factor sample group. One ASD participant showed 0% accuracy in the subordinate ambiguous condition. Excluding him from the analysis did not change overall results, thus the participant's data was retained in the analysis.

In Appendix H.2, descriptives can be found in Table *H.41* (TD) and Table *H.42* (ASD). Inferential results are in Table *H.46* and Table *H.47*.

#### 9.2.4.1 Results

##### *9.2.4.1.1 Overall Performance, Contextual Facilitation and Suppression*

In terms of RTs in the facilitation condition, a 2x2x3 ANOVA with the factors context (biased, neutral), dominance (dominant, subordinate), age group (child, adolescent, adult) and sample group (ASD, AmTD) revealed that the only sample-specific effect regarding RTs was a main effect of sample ($p$ = .004). The same was found in the suppression condition with the 2x2x3 ANOVA with the factors ambiguity (ambiguous, unambiguous), dominance, age group and sample group (main effect of sample, $p$ = .005). In the facilitation condition (TD: $M$ = 920ms; ASD: $M$ = 1104ms) as well as suppression condition (TD: $M$ = 1061ms; ASD: $M$ = 1226ms) ASD participants responded slower than AmTD.

In the analysis of accuracy in the suppression condition, the main effect of sample group and its interactions were not significant ($p$ > .05). Similarly, no sample effects were found in most of the contextual facilitation and suppression indicators ($CFR_{RT}$, $TFR_{RT}$, $CSR_{RT}$, $TIS_{RT}$, $TFS_{ACC}$, $CSR_{ACC}$ and $TIS_{ACC}$, all $p$ > .05).

However, in the analysis of accuracy in the facilitation condition significant interactions with sample group were found: Dominance x Age Group x Sample Group ($p$ = .019) and Context x Dominance x Age Group x Sample Group ($p$ = .006). Further inspection of the 4-way interaction showed that compared to ASD children, TD children had higher accuracy in the dominant neutral (unbiased) condition, but lower accuracy in the subordinate neutral condition (cf. Figure 9.6a). Further, AmTD children had lower accuracy in dominant biased sentences than in subordinate biased sentences ($p$ = .044). The AmTD children were also the only age group where responses to dominant biased sentences were significantly less accurate than to neutral (i.e. unbiased) dominant sentences ($p$ = .049), overall indicating a stronger effect of dominance in this age group.

The $CFR_{ACC}$ analysis showed significant interactions of Dominance x Age Group x Sample Group ($p$ = .003). The $CFR_{ACC}$ in the dominant condition differed significantly between TD and ASD in children with ASD children showing a higher contextual facilitation $CFR_{ACC}$ ($M$ = 1.06) than TD ($M$ = 0.95, p = .017). There was no difference between TD and ASD in the other age groups (cf. Figure 9.6b).

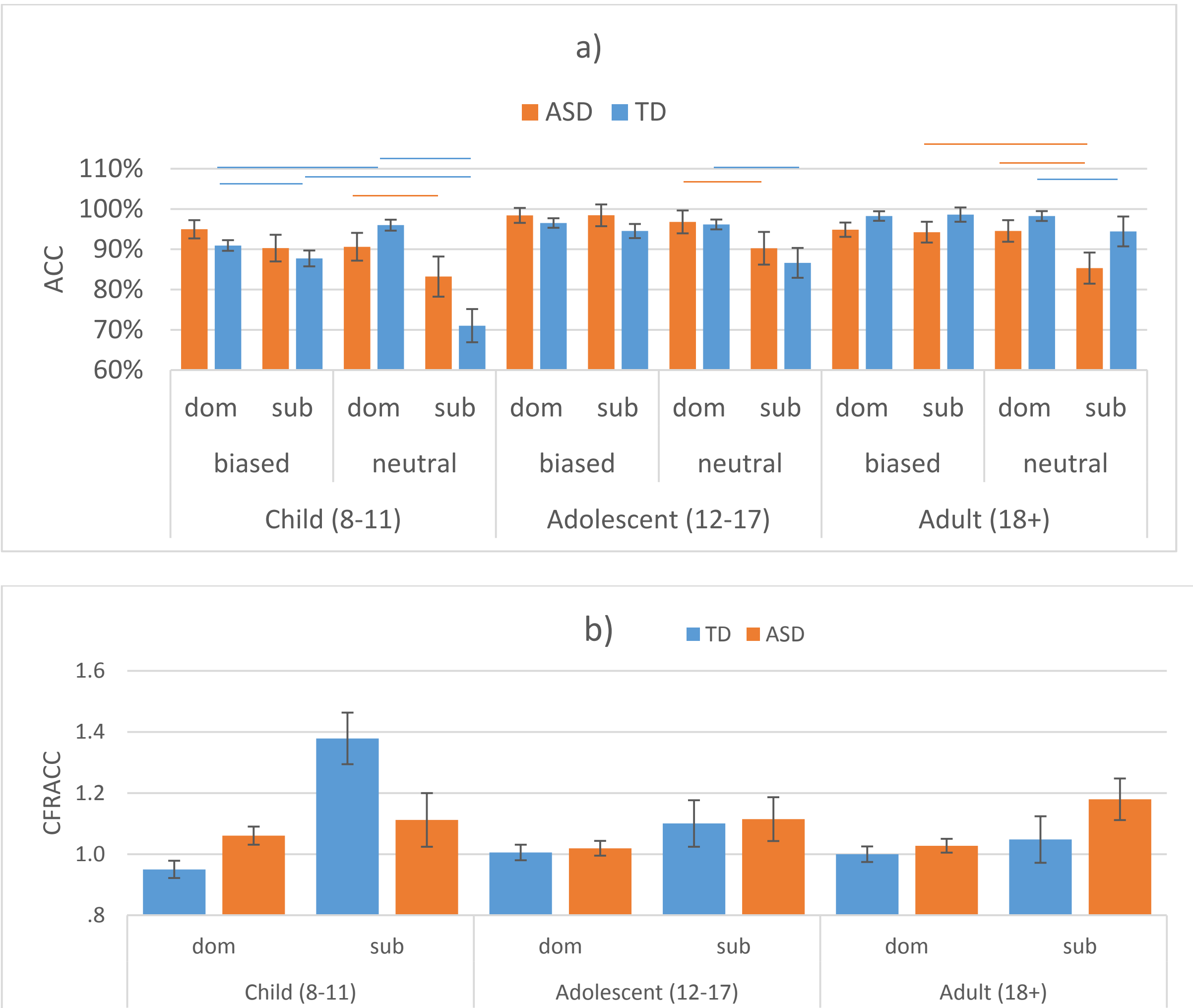



*Figure 9.6.* a) accuracy data and b) Context facilitation ratio $CFR_{ACC}$ for ASD participants and AmTD participants in AMBSENT (Facilitation Condition).
ACC is presented for sentences with biasing context and neutral context, and for dominant (dom) vs subordinate (sub) meanings. The higher the CFR, the more participants benefited from the context information (CFR = 1: no significant facilitation). Error bars represent standard errors. ─ indicate significant differences in accuracy between conditions (blue for TD, red for ASD).

#### 9.2.4.1.2 *Prevalence of Atypical Performance analysis*

The AP analysis (Table 9.4) showed that a higher percentage of ASD individuals (e.g. 1/4th of ASD children) had extremely high RTs or low accuracy. The result pattern regarding contextual facilitation and interference (combined for dominant and subordinate meanings) was similar between groups, although 17% of ASD adolescents showed lower interference (thus, higher contextual suppression) than their TD peers, while accuracy was in the normal range for all those participants (0% AP).

Table 9.4

*Percentage of individuals in each age and sample group with atypical performance (z > 1.645) in AMBSENT*

| | TD | | | | ASD | | | |
|---|---|---|---|---|---|---|---|---|
| | child | adolescent | adult | total | child | adolescent | adult | total |
| higher RT | 5% | 4% | 4% | 4% | 25% | 17% | 10% | 16% |
| lower ACC | 5% | 4% | 8% | 6% | 25% | 0% | 20% | 14% |
| higher facilitation | 10% | 4% | 13% | 9% | 8% | 11% | 5% | 8% |
| lower facilitation | 5% | 4% | 4% | 4% | 8% | 0% | 5% | 4% |
| higher interference | 10% | 9% | 8% | 9% | 8% | 6% | 15% | 10% |
| lower interference | 0% | 0% | 0% | 0% | 0% | 17% | 0% | 6% |

*Note. The $TFR_{RT}$ and $TFR_{ACC}$ were combined to a total facilitation score TFR. The $TIS_{RT}$ and $TIS_{ACC}$ were combined to a total interference score TIS. Higher interference also indicates lower contextual suppression.*

### 9.2.4.2 Summary and Discussion

Overall, as expected, no major differences were found between TD and ASD participants and the patterns of results were in mostly the same for both sample groups. Differences were found in the following aspects:

In terms of RTs, ASD participants responded slower than AmTD participants and there was a higher percentage of AP in the ASD group, especially in children (25%). This could indicate higher processing demands in the ASD group. Interestingly, the prevalence of AP in ASD reduced with age, which suggests that although children showed poorer performance than TD peers, by the time they reached adulthood, some of them caught up in development and perform comparably to TD. This is in contrast to the findings regarding RTs in AMBWORD where the AP prevalence increased with age which was interpreted as a slower developmental trajectory (cf. Figure 9.7). A speculative explanation for the findings is that processing single ambiguous words in isolation put a higher cognitive demand on ASD compared to TD. However, when the words were embedded in sentence context and local coherence was required to process them efficiently, cognitive demand also increased for the TD group and their performance slowed (and also impacted accuracy as will be discussed below). In participants with ASD, especially older ones, performance did not slow down as much, reducing the difference in AP between the samples, potentially as local coherence is a relative strength in the ASD group and develops at a faster rate compared to TD.

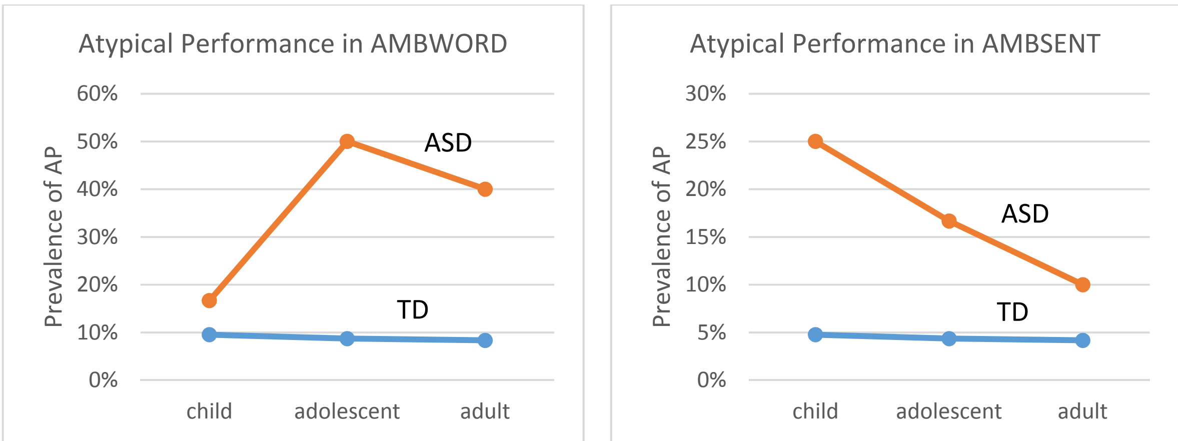



*Figure 9.7.* Prevalence of atypical performance (AP) regarding RT in the tasks AMBWORD and AMBSENT in TD and ASD.

In terms of accuracy, the group means were in general comparable between ASD and AmTD, although the AP analysis showed a higher prevalence of low accuracy in the ASD children and adults. There were specific effects in AmTD children that were not found in older TD or any ASD participants: they had higher contextual facilitation ($CFR_{ACC}$) for subordinate meanings than all other groups which was mainly based on their low accuracy in the unbiased condition (e.g. She wanted a BALL → dance ball picture). The increased $CFR_{ACC}$ needs to be interpreted not as better context use but a more detrimental effect of meaning dominance in TD children than the other groups, i.e. neutral sentences were more likely to activate (only) the dominant meanings (cf. Figure 9.6a). The pattern in ASD children was similar to the older groups.

AMBSENT was classed as a local coherence task. According to other researchers, local and global processing develop alongside each other (Happe & Booth, 2008) and individuals with ASD have a local processing advantage (Booth & Happé, 2010; Happe & Frith, 2006; Mottron & Burack, 2001; O'Riordan & Plaisted, 2001). Both accounts could be reflected in the current data: Local coherence develops with age in TD, which is why (at least some) TD children showed more difficulty in this task compared to the older groups. In ASD however, local coherence could be a strength and reach a sophisticated level earlier in life; thus, children with ASD showed similar performance to the older groups (and as discussed above regarding response speed, ASD adults could benefit relatively more from local coherence than TD adults). This would further be evidence for the notion that tasks involving single sentences are indeed not global, but local tasks (Hahn et al., 2015; Happe & Frith, 2006; Jolliffe & Baron-Cohen, 1999; Vulchanova, Talcott, Vulchanov, Stankova, et al., 2012).

Norbury (2005) advocated that poor contextual processing in AMBSENT might be a feature not of ASD but comorbid language difficulties. She showed that participants with language impairment (LI) performed similarly poor to those with ASD plus LI, whereas those participants with ASD but no LI performed similarly to TD. Although we did not examine this effect directly, the current results do not contradict Norbury’s account, as the ASD participants (without LI) performed similarly to TD; however, as discussed there were specific differences between the samples that were revealed by a more comprehensive analysis. For example, in contrast to our study, Norbury did not differentiate between dominant and subordinate meanings when calculating facilitation and suppression scores, thus, findings specific for only one condition could have been overlooked (e.g. that TD children have higher CFR for subordinate but not dominant meanings). Furthermore, Norbury analysed all 9-17 year-olds as one group which could have masked effects that were only present in the younger children (e.g. the large effect of meaning dominance in TD children that was found in our study). We have shown in the VISTA study and the so far presented language tasks that performance of adolescents aged 12+ was more similar to the performance of adults than to younger children aged 8 to 11 years. We, therefore, advocate that future research should not combine children and adolescents in one group. The cut-off age at which child-like performance ends and adult-like performance begins may potentially be different from the one chosen in the current study. This would need to be examined in further research with a larger sample where age could be used as a continuous variable in the analysis.

In sum, the results for the task AMBSENT showed that participants with ASD performed slower than TD, although the prevalence of AP decreased with age. Mean accuracy was comparable between sample groups, but there was a higher prevalence of low accuracy in ASD adults and children. TD children showed a higher dominant advantage in unbiased sentences compared to ASD peers or older TD participants, whereas the effect was not found in ASD children who performed similarly to the older groups. Thus, compared to TD children, subordinate meanings were more likely to also be activated in ASD children when embedded in a neutral sentence. Furthermore, no TD participants showed lower than average interference (thus higher contextual suppression) in the AP analysis, whereas 17% of ASD adolescents did despite their overall accuracy being in the normal range (0% AP). Together, these results seem to suggest that despite posing generally higher cognitive demand on ASD participants as reflected in the RT data, there were indications that local coherence as measured by this task could be a relative strength in ASD.

### 9.2.5 SENTORD: Global coherence in ASD participants

#### 9.2.5.1 Results

The analyses were equivalent to Section 9.1.5, just with the additional between-subjects factor sample group (ASD, AmTD). One ASD child (AC-21) did not solve any stories correctly. The analysis was conducted with and without his data, but results were comparable. The reported results include this participant.

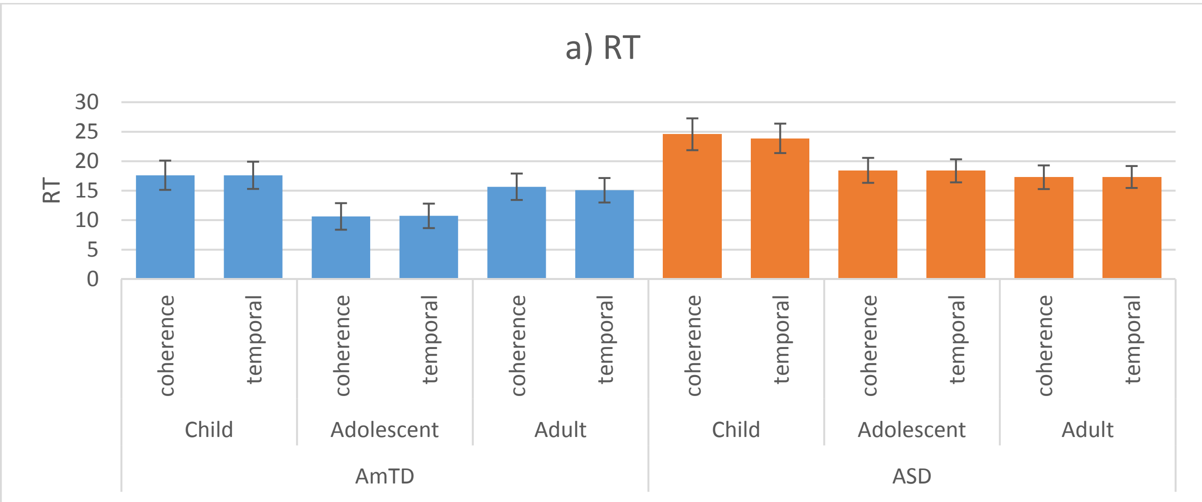
Descriptive data can be found in Appendix H.3.1, Table H.48, and inferential results can be reviewed in Appendix H.3.2, Table *H.51*.

No speed-accuracy trade-off was found overall or in any age group or condition ($p > .05$).

#### *9.2.5.1.1 Comparison of Overall Performance in ASD and AmTD*

The ANOVAS with the factors condition (temporal, coherence), age group and sample group showed that ASD participants were slower in ordering the sentences than AmTD participants ($M = 20.0$ seconds and $M = 14.6$ seconds respectively, main effect of group: $p = .002$, cf. Figure 9.8a), and also less accurate ($M = 63.8\%$ and $M = 76.7\%$, main effect of group: $p < .001$, especially in children, cf. Figure 9.1b). For accuracy, the interaction Condition x Age Group was not far from significant ($p = .057$, $p = .062$ without participant AC-21) and was therefore explored further. In children, there was no difference between the temporal and coherence condition ($M_{diff} = 0$, $p > .05$), whereas the difference became larger with increasing age (adolescents $M_{diff} = 5.8\%$, $p = .081$; adults $M_{diff} = 12.2\%$, $p < .001$).

The pattern of results in ASD was identical to the AmTD group: No significant interactions with sample group were found in any of the analyses (RTs, accuracy, $TempFR_{RT}$, $TempFR_{ACC}$). Like in AmTD, the only age group that showed a significant temporal facilitation ($TempFT_{ACC} \neq 1$) was the ASD adult group, $t(19) = 2.984$, $p = .008$.



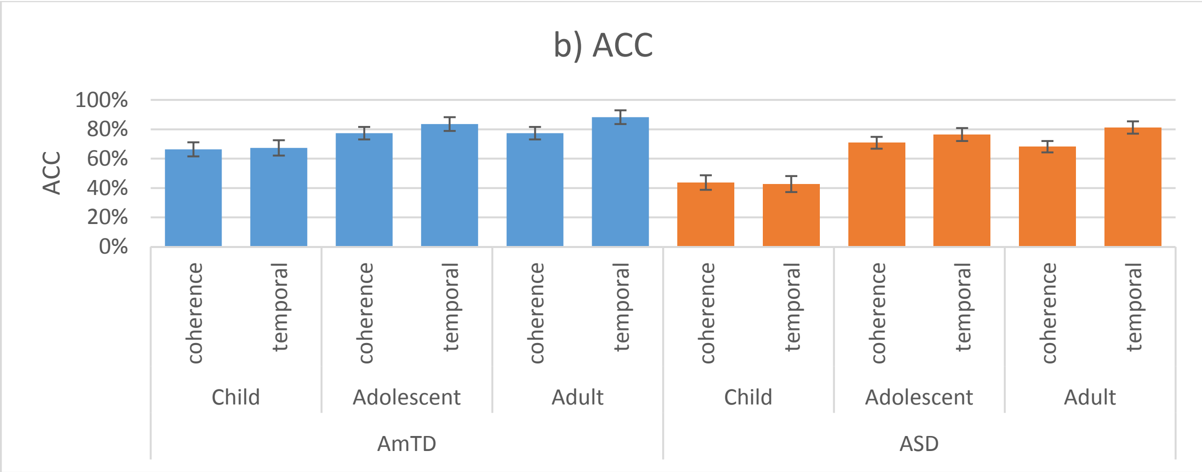



*Figure 9.8.* a) RT and b) accuracy data for AmTD and ASD samples in the task SENTORD.

### *9.2.5.1.2 Prevalence of Atypical Performance*

The AP analysis (Table 9.5) showed that there were more extreme cases in the ASD groups regarding RTs and accuracy in both, coherence and temporal condition. In both samples, there were more participants with low accuracy in the temporal condition than in the coherence condition. While the AP prevalence in ASD reduced with age for accuracy (especially in the temporal condition), it remained relatively stable regarding RT. Temporal Facilitation in both sample groups was comparable.

*Table 9.5*

*Percentage of individuals in each age and sample group with atypical performance (z > 1.645) in SENTORD*

| | TD | | | | ASD | | | |
|---|---|---|---|---|---|---|---|---|
| | child | adolescent | adult | total | child | adolescent | adult | total |
| lower accuracy - coherence | 5% | 0% | 4% | 3% | 33% | 6% | 20% | 18% |
| lower accuracy - temporal | 14% | 4% | 13% | 10% | 67% | 6% | 15% | 24% |
| | | | | | | | | |
| higher RT - coherence | 5% | 4% | 8% | 6% | 25% | 33% | 20% | 26% |
| higher RT - termporal | 0% | 0% | 8% | 3% | 17% | 44% | 15% | 26% |
| higher TempFacil | 5% | 9% | 4% | 6% | 0% | 11% | 5% | 6% |

*Note. TempFacil = Temporal Facilitation averaged over* $TempFR_{RT}$ *and* $TempFR_{ACC}$

### 9.2.5.2 Discussion

The analysis of SENTORD showed that participants with ASD performed similarly to the age-matched controls. Their sentence ordering took longer and was less accurate (as shown by the ANOVA and AP analysis), which indicates that the task was more demanding for them. Interestingly, the prevalence of AP regarding accuracy was high in ASD children compared to their peers, but the difference reduced with age. This could indicate that after a developmental delay during childhood individuals with ASD were able to catch up with the TD participants.

We expected to find higher temporal facilitation and lower accuracy in the coherence condition in ASD; however, no differences were found between the coherence and temporal conditions regarding RTs, and accuracy did not differ much between conditions, although adults were more accurate in the temporal condition. Thus, the same pattern was found as in TD. The results are in contrast to those of Jolliffe and Baron-Cohen (2000) and Vulchanova, Talcott, Vulchanov, Stankova, et al. (2012) who found reduced accuracy in the coherence condition in ASD.

During the testing, some observations were made that could explain increased RTs (and potentially reduced accuracy) in the ASD group: First, in the story about *Adam's birthday*, some participants questioned why the family would have cake as a dessert after breakfast (*You don't eat cakes for breakfast!*); thus, arranging the story took longer time in those participants. Second, in the (temporal) stories *Making a garden look nice*, *Preparing and cooking a dinner*, and *A woman's day at work,* sentences arranged based on the temporal cues *lunchtime*, *dinner* and *afternoon* could have been ordered incorrectly: some ASD participants argued that *lunchtime* would usually be in the early to mid-afternoon, and at least one adult participant elaborated that *lunch* was only a packed lunch, and *dinner* a cooked meal at home around midday. Different definitions of those terms can reflect class differences[3]. Unfortunately, no record was taken at the time of testing regarding which participants they were, so their performance could not be analysed in more detail. Clearly, ASD participants were more particular about the details in the stories compared to TD which potentially, instead of resulting in better performance in the temporal condition, has led to poorer performance overall. The fact that individuals

[3] "There is nothing wrong with the word 'dinner in itself: it is only a working-class hallmark if you use it to refer to the midday meal, which should be called 'lunch'. Calling your evening meal 'tea' is also a working-class indicator: the higher echelons call this meal 'dinner' or 'supper'." (From the book *Watching the English: The Hidden Rules of English Behaviour* by Fox, 2005)

with ASD are specific about wording has previously been reported by Scott et al. (as cited in Happe & Frith, 2006) who found differences in performance when ASD participants were asked in tasks instructions whether two illusionary pictures *were* the same or *appeared* the same.

One could further argue that some stories in the temporal condition were in fact as difficult as or even more difficult than the coherence condition. Identifying the cues and then interpreting and arranging the sentences in the correct order could have been counterintuitive, for example, in the story about the fireman's shift (original story from Jolliffe & Baron-Cohen, 2000): the story starts in the afternoon and ends in the morning (see Figure 6.7 on page 102 and Appendix C.5). Thus, additionally to the temporal cues in this story, the overall context had to be considered for a correct arrangement of the sentences; arguably, global processing was required and sole reliance on the temporal cues would have led to an incorrect result. A disentanglement of such local and global processing requirements would have produced a clearer picture of the differences between the temporal and coherence condition.

Given the high prevalence of AP (e.g. up to 67% regarding accuracy in children), it was decided to perform a more in-depth examination of the AP data. A closer analysis of the AP patterns across language tasks revealed that strikingly, there were participants who performed comparably very poor in the SENTORD task but at ceiling in the other language tasks (but also those who performed poor in the other tasks but well in SENTORD; see Figure 9.9 on p. 236 for a depiction of accuracy in SENTORD vs AMBSENT). An explanation why the participants showed intact performance in the less complex tasks but struggled in SENTORD could be that in SENTORD, more information had to be held and manipulated in WM simultaneously. Koolen and colleagues have found differences in EF between TD and ASD, especially in monitoring WM representations, but only once the to-be-retained information became more complex (Koolen, Vissers, Egger, & Verhoeven, 2014; Koolen, Vissers, Egger, & Verhoeven, 2013, see also review by Kercood et al., 2014). This is also consistent with the overall finding that the differences in RTs and accuracy between the ASD and AmTD samples were larger with increasing complexity of the tasks (AMBWORD $M_{diff\text{-}ACC}$ = 0.3%, $M_{diff\text{-}RT}$ = 127ms; AMBSENT $M_{diff\text{-}ACC}$ = 0.8%, $M_{diff\text{-}RT}$ = 158ms; SENTORD $M_{diff\text{-}ACC}$ = 10.6%, $M_{diff\text{-}RT}$ = 4.9sec). Fittingly, ASD has previously been depicted as a complex information processing disorder (cf. Van Eylen et al., 2018). We would, therefore, argue that reduced performance in highly verbal participants with ASD in more complex language tasks like SENTORD is due to the increased demand they pose on EF, especially WM and not, for example, reduced global processing abilities.

In sum, there was no evidence of reduced global processing abilities in the SENTORD task. Instead of a global coherence difficulty, performance in both conditions was impaired, especially in ASD children, presumably due to limitations in EF. As the prevalence of AP reduced with age this could be interpreted as an initial developmental delay in younger individuals, whereas older ones may catch up with their peers either due to improved EF or the development of compensation strategies.

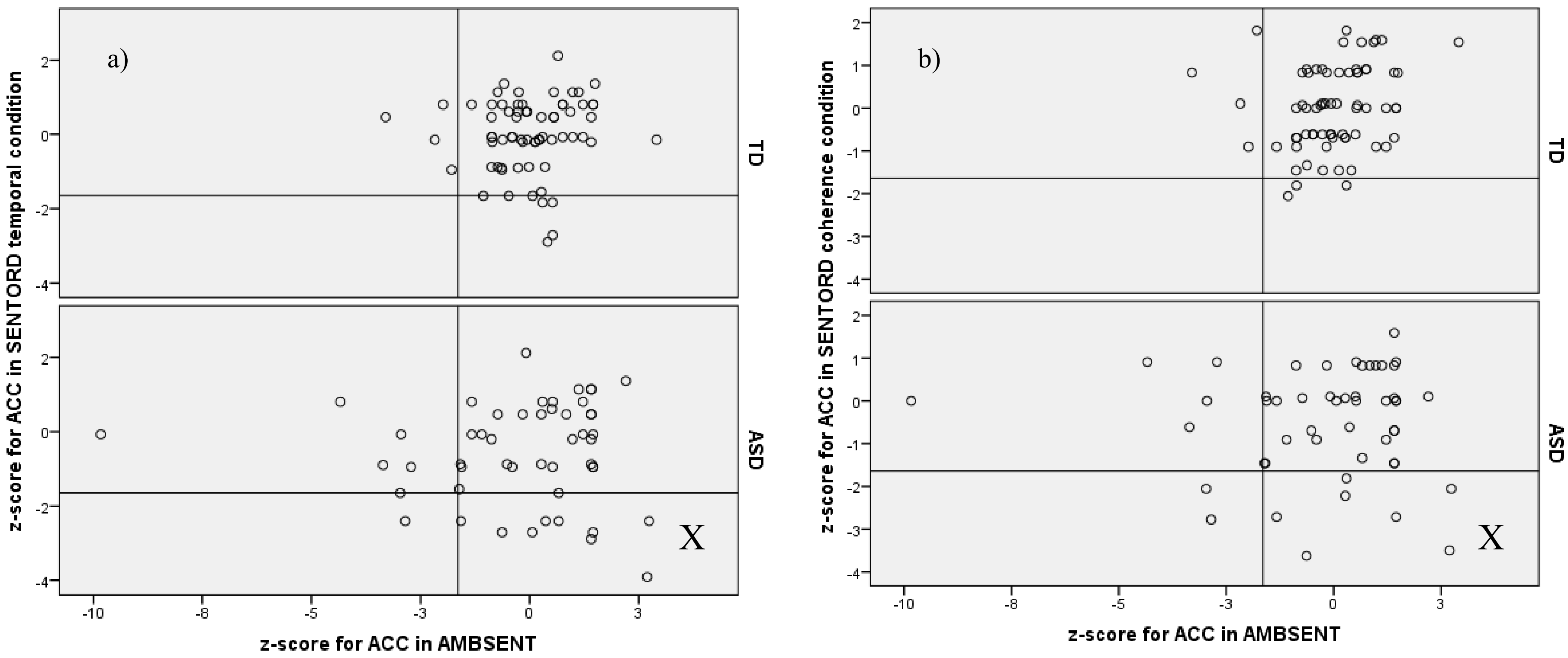



*Figure 9.9.* Depiction of z-scores for accuracy in AMBSENT and SENTORD temporal condition (a) and coherence condition (b) for ASD and TD participants. Vertical and horizontal lines indicate the cut-off for atypical performance at z = -1.645. Lower scores indicate poorer performance. The bottom right quadrant in ASD (marked with X) contains participants who scored in the normal range or above average in AMBSENT but showed AP in the SENTORD.

### 9.2.6 SENTCOMP: Language processing styles in ASD

The majority of ASD participants (N = 43 out of 50) completed the Sentence Completion Task. Booth and Happe (2010) provided normative TD data for males and females aged between 8 and 25 years as well as data from ASD children and adolescents (HFA and AS) that can be used to compare the current TD as well as ASD data to. See Table H.52 in the appendix for descriptive data of both studies and Figure 9.10 for a depiction of the performance in the current ASD group.

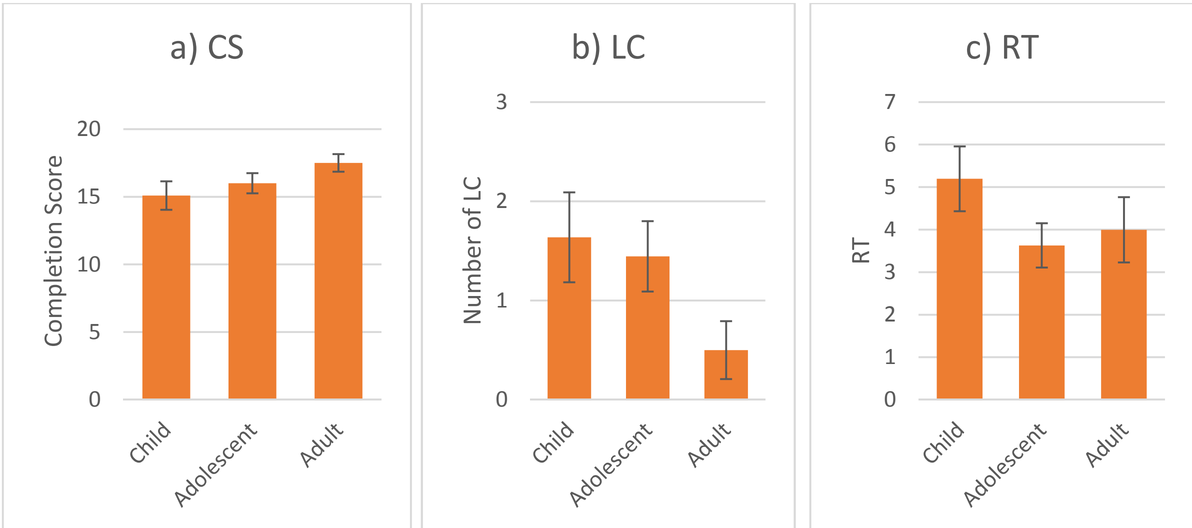



*Figure 9.10.* A) Completion score (CS), b) number of local completions (LC) and c) RT (RT) in the current ASD sample.
Error bars are standard errors.

#### 9.2.6.1 Results

##### *9.2.6.1.1 Comparison of the current data to Booth and Happe's (2010) data*

The current TD data had an insufficient sample size (see Section 9.1.6); therefore, z-scores were calculated for the ASD data of the current study (cASD) based on the data of Booth and Happe (BH, 2010). The current ASD adults could not be compared, as no ASD adults were tested in BH's study.

*Completion Score*

In terms of the CS, the cASD children and adolescents did not differ from BH-ASD children and adolescents (cf. Table 9.6 for statistics). Further, the cASD children and adolescents differed from BH's

A)

Aston University

Illustration removed for copyright restrictions

B)

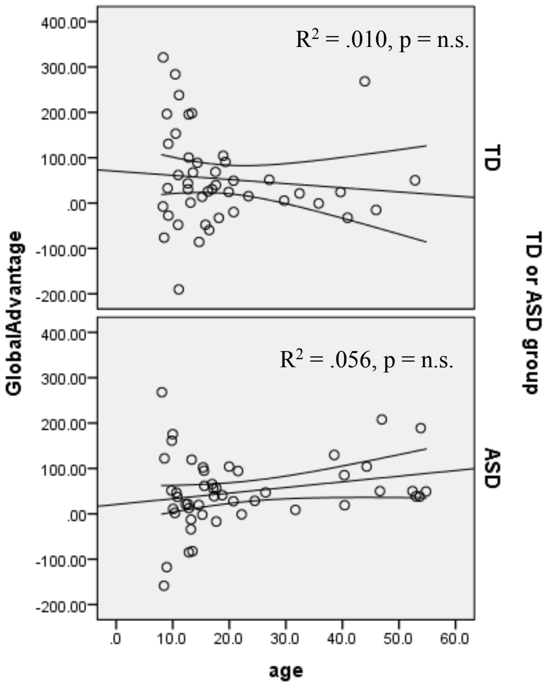



*Figure 8.15.* Comparison of the relationship between age and global advantage in (A) Scherf et al. (2008, p. 133) and (B) the current study.
Global advantage is shown as a function of age with 95% confidence intervals. A) Global advantage = [(local inconsistent–local consistent) – (global inconsistent–global consistent)]. B) Global advantage = local – global. Explained variance in (B) for TD: $R^2 = .010$ (n.s.); for ASD $R^2 = .056$ (n.s.).

It could be argued that the task used was unsuited to discover age effects in the samples. The analysis of the accuracy data, for example, showed no overall perception bias at all (neither in TD nor ASD). Potentially, a more difficult task would have been better able to elicit age differences in the perception bias; however, despite not finding age differences in the biases, differences were found in the RT and accuracy data: both, TD and ASD children responded slower and less accurate than the older groups. Thus, the tasks allowed for a certain amount of variation between participants which could have also been reflected in variability in the bias.

###### 8.2.3.2.2 *Can participants with ASD of all age groups flexibly adjust their biases and how do they compared to TD?*

Based on the findings that EFs including cognitive flexibility are reduced in ASD, it was expected that the CE might be reduced in ASD. However, this was not confirmed. Equivalently to Hayward et al (2012) and Iarocci et al. (2006), participants with ASD were able to shift their global bias (regarding (*p* = .057). The cASD adolescents and adults needed significantly more time for responses than did BH TD adolescents and adults.

No differences were found between cASD age groups in a Kruskal-Wallis Test, $\chi^2(2) = 4.360$, $p = .113$.

##### *9.2.6.1.2 Categorisation of participants into displaying a local processing style*

Equivalently to Booth (2006) and the TD analysis in Section 9.1.6, the participants were categories as displaying weak central coherence if they provided two or more local completions. This applied to 5/11 ASD children, 7/18 ASD adolescents and 1/14 ASD adults, or 13/43, i.e. 30.2% of the whole ASD sample. This is slightly lower than what Booth (2006) reported for their ASD group (they did not differentiate between ASD age groups, cf. Table 9.7).

*Table 9.7*
*Percentage (and N/total N) of participants in each group who showed weak central coherence in the SENTCOMP task.*

| Booth (2006) | TD | | Aston University Illustration removed for copyright restrictions | | | |
|---|---|---|---|---|---|---|
| | 7-11 | 12-17 | 18+ | 8-11 | 12-17 | 18+ |
| | 33% (1/3) | 33% (1/3) | 10% (1/10) | 46% (5/11) | 39% (7/18) | 7% (1/14) |

*Note.* Booth's (2006) controls were age- and ability-matched to the ASD sample.

#### 9.2.6.2 Discussion

Overall, the performance of the current ASD group was comparable to Booth and Happe's (2010) ASD group. Compared to Booth and Happe's TD sample, all current ASD age groups made more local completions and had lower CS compared to the equivalent TD groups, although the difference between the adult groups was not significant for the CS. ASD children (although not significant), adolescents and adults needed more time to provide completions than the TD groups. In the ASD group, there was a tendency for children and adolescents to give more LC than adults. These results clearly show that, as predicted, participants with ASD had a more local response style in SENTCOMP which, according to Booth and Happe (2010) indicates weak central coherence.

In Section 9.1.6, we reported that in TD adults, VP correlated positively with CS, negatively with RTs, but not with LC. This was not found in the current ASD sample. Booth and Happe (2010) also reported mixed results regarding the relationship between CS and intellectual ability: In one of their ASD sample (mean age 11yrs) there was a significant correlation, whereas in the other ASD sample (mean age 14.4yrs) and in TD, this relationship was not found. It was also missing in a control group and ADHD group which both included participants with intellectual impairment. The authors concluded that a local processing style is independent of ability but indeed reflects a cognitive style. The current results support the lack of relationship between a local response style and intellectual ability in ASD.

In Booth and Happe's study, the percentage of TD individuals that showed a local processing style generally decreased with older age. The authors did not differentiate between age groups in ASD; however, the current results also showed a reduction in local processing style from nearly half of all children to only 7% of ASD adults. Thus, in both, TD and ASD, local processing styles reduce with age. Fittingly, Edgin and Pennington (2005) found in a cross-sectional sample of children aged 7 to 17 that younger children with ASD had a local processing advantage; however, this advantage levelled out with increased age. Booth and Happe (2010) suggest that those participants with ASD who did not give local completions might have recognised the (implicit) global nature of the task and applied compensation strategies to avoid local completions. This could be a reason for a less local processing style in older groups. Previous researchers (Hala et al., 2007; Henderson et al., 2011) have suggested that implicit tasks (for example like SENTCOMP) might lead to poorer contextual processing in ASD than more directive/explicit tasks (like in AMBSENT). Similarly, Van Eylen and colleagues suggested that participants with ASD could compensate for their deficits (in a cognitive flexibility task) when task instructions were explicit (Van Eylen et al., 2011) and showed that deficits in ASD were more pronounced in open-ended more implicit tasks (Van Eylen, Boets, Steyaert, Wagemans, & Noens, 2015).

Together, this could explain why the current ASD participants performed comparably to TD in AMBSENT but showed a higher prevalence of a local style in SENTCOMP, despite both tasks involving the use of context in single sentences. EFs contribute to response monitoring and the accompanying compensation strategies (Reis, McGuire, & Neu, 2000).

In sum, lower SENTORD performance in ASD could be attributed to the increased complexity and implicit nature of the task. After showing a high prevalence of AP in children, performance improved and AP prevalence reduced with age, probably as a result of increased response monitoring, compensation strategies and therefore EF in older participants.

## 9.3 Summary of Findings and Discussion

In this chapter, performance in four language tasks measuring different aspects of local and global language processing was compared between a cross-sectional sample of individuals with ASD and a normative TD sample in order to examine LGLP in typical development as well as to answer the question whether and how LGLP in ASD differed from processing in TD. Following, results and conclusions that were derived from the comprehensive analysis of the data will be presented.

*Typical development and performance*

TD children showed higher interference from dominant or irrelevant meanings, i.e. reduced inhibitory control, than older groups when processing single words in isolation (AMBWORD) or in sentence context (AMBSENT). The ability to suppress irrelevant information developed with age.

Children showed high contextual facilitation; thus, the ability to use context to activate relevant meanings was already developed at a young age. It was suggested that contextual facilitation was an aspect of central coherence, which might be already relatively sophisticated in younger individuals. For contextual suppression, however, central coherence is necessary as well as inhibitory control (an EF) which is still developing until adulthood (cf. the previous paragraph).

The use of local cues in more complex language tasks (SENTORD) developed with age, as did the overall ability to manipulate larger amounts of information and to choose and switch to the best strategy (here: local or global processing) for the completion of a task. Thus, WM and cognitive flexibility, both aspect of EF, increase with age.

A local processing style (or preference) in SENTCOMP was found not only in ASD but also some TD individuals. Based on Booth and Happe's (2010) conclusions, this was interpreted as weak central coherence and not a result of hasty responses due to reduced inhibitory control. However, the interpretation that EFs were not involved in the local response style was subsequently undermined considering the results from the ASD group (see below).

It was concluded from the analyses that when TD individuals of different ages were to be allocated on positions in the four field matrix of weak to strong local and global coherence (based on Happe and Frith, 2006), children would develop from having relatively weak global as well as weak local abilities to strong local and global abilities in adulthood (cf. Figure 9.5 on page 222). Older participants were then more able to shift between local and global processing (cognitive flexibility). Booth (2006) adopted a similar approach categorising her participants. She differentiated between global dominant, local dominant, poor adaptive and good adaptive performers (i.e. those that are able to select and shift their processing level depending on the task). She found that with increasing age, the prevalence of poor adaptors decreased while good adaptors increased. Further, the percentage of local dominant performers decreased slightly, while the percentage of global dominant ones remained relatively stable. Thus, the main development regarding LGP concerned the ability to shift between processing styles and to select the most appropriate level, which has also been suggested by other researchers (e.g. Huizinga et al., 2010). This was supported by the current data and also deducted from the results of the VISTA study (Chapter 8).

*Performance and Development in ASD compared to TD*

The group with ASD individuals showed higher RTs but comparable accuracy to TD in the more simple language tasks involving single words and single sentences which could indicate higher cognitive demand in ASD. Accordingly, the prevalence of atypical performance (AP) in those tasks was higher in ASD; Different developmental trends were observed in the AP regarding RTs in both tasks: While the AP analysis in AMBWORD pointed towards an increasing developmental delay in ASD with higher age (i.e. higher prevalence of AP), the analysis in AMBSENT was suggestive of a developmental delay that, in fact, reduced with age, potentially due to a faster development of local coherence abilities in ASD compared to TD (see also the next point). Prevalence of AP in terms of accuracy did not show such developmental trends.

While some TD children had difficulties accepting subordinate meanings in unbiased sentences in AMBSENT, this was not the case for ASD children who performed similarly to the older groups. It was hypothesised that this could reflect a relative strength in local coherence in ASD children who reach a relatively good level already earlier than TD.

Equivalently to TD, the SENTORD performance of the ASD groups showed improved use of local cues and overall performance with age, implying enhanced adaptability of the processing style in older participants. However, despite showing the same trends as in the TD groups, participants with ASD needed more time and were less accurate in ordering sentences to meaningful stories, independently of whether they belonged to the local or global condition. The AP analysis showed that the prevalence of AP in terms of accuracy was high in ASD children but decreased older age groups which could be interpreted as indicating a slower developmental trajectory in ASD (while AP regarding RTs was relatively stable). It was hypothesised that performance in the more complex SENTORD task was reduced in participants with ASD due to the increased demand it posed on WM. To our knowledge, to date, no studies have evaluated developmental trajectories of WM in ASD.

More individuals with ASD, especially in the younger participants, showed a local processing style in SENTCOMP compared to TD, as they did not take the context of the sentence stem into account when giving completions. This was in contrast to the results from the more explicit task AMBSENT, where contextual processing was intact in ASD. The implicit nature of SENTCOMP could have led to less response monitoring and less compensation in ASD participants, and thus, the apparent reduced global processing. Booth and Happe (2010) interpreted increased local completion as an indicator of weak central coherence in contrast to poor inhibitory control; however, we would argue that EF does play a role at least in some if not all cases, as we identified number of participants who performed (very) well on the explicit AMBWORD task but showed very poor performance on the implicit SENTORD task, probably due to reduced response monitoring. Given that the prevalence of a local response style reduced with age, this could indicate improved response monitoring and compensatory strategies, which are related to EF (Reis et al., 2000).

Overall, it seems that it was not local or global processing abilities per se that influenced the performance of ASD participants on the assessed tasks, but various aspects of EF (WM, cognitive flexibility, response monitoring, inhibitory control/suppression). Instead of conceptualising LGP in a two-dimensional space from weak to strong local and global processing—which might be appropriate to describe TD individuals—we, therefore, advocate that a third dimension, EF, needs to be considered when examining individuals with ASD (Figure 9.11).

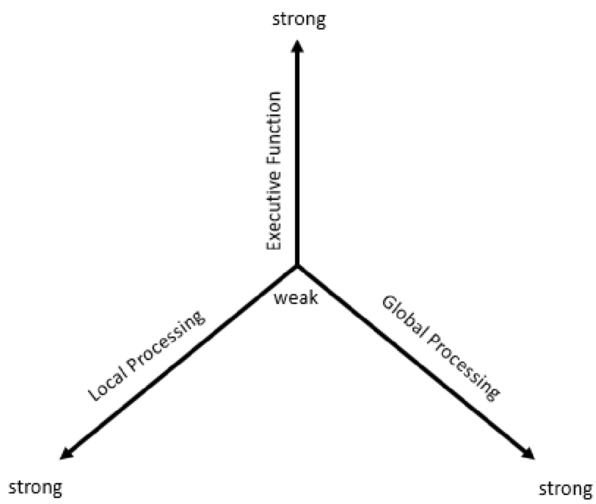



*Figure 9.11.* Local and global processing in a three-dimensional space with executive functions as the third dimension.
For example, the majority of TD adults show strong EF including cognitive flexibility and will vary mainly on the two dimensions of LGP. Those with ASD will also vary more on the dimension of EF (and different aspects of it) which will impact their performance on LGP tasks.

An overview of aspects of LGP, EF and other factors that seem to have influenced performance in the language task is presented in Table *9.8*. Also included are the developmental trends that were found regarding AP in ASD, and suggested trends for overall performance of TD versus ASD individuals. Depending on the task and whether RTs or accuracy were considered, the ASD group showed developmental delay with a) small deficits but with the development occurring at the same rate (the ASD trajectory is running underneath and parallel to the TD group); b) deficits but with a slowed development (the ASD trajectory is running underneath and has a lower slope); or c) a developmental delay with deficits that reduced with age (the ASD trajectory is running underneath and has a steeper slope). Nevertheless, the here suggested trends are only indications and different trajectories might be found for different subgroups of individuals with ASD given the heterogeneity of the disorder. For example, Fountain, Winter, and Bearman (2012) presented six different trajectories of social and communication functioning that characterised children with ASD. Interpretations of developmental trajectories based on cross-sectional samples like in the current study, especially with relatively small sample sizes, have to be treated with caution and would need to be validated in a longitudinal design and/or more participants.

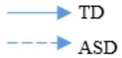
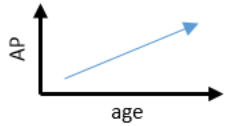
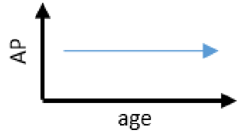
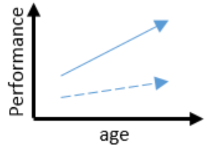
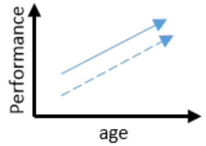
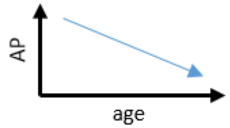
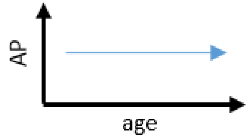
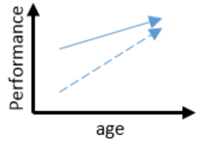
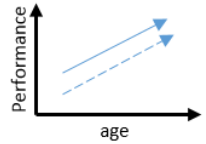
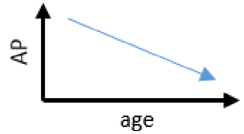
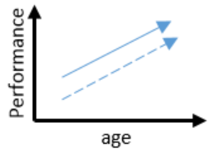
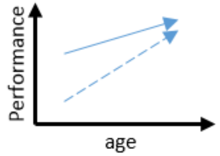
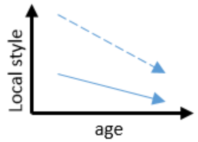
### 9.3.1 Limitations

A couple of limitations need to be considered specifically in terms of the LANTA study (for more general methodological considerations of this investigation see Section 11.6).

According to Riches et al. (2016), language tasks measuring LGP focus exclusively on the ability of global integration (AMBSENT, SENTORD, SENTCOMP) and are therefore not assessing local processing abilities. The authors developed an alternative task which according to them measure enhanced local processing. Participants are asked to decide whether picture that followed syntactically ambiguous sentences (e.g. *the girl approached the butterfly on the log*) could represent the meaning of the sentence. It thus tests the ability to focus on the local aspect (two possible interpretations of the sentence: the girls sits on the log floating on a river vs. the butterfly sits on the log), at the expense of global information which would be reflected in the plausibility of the interpretation and involve background assumptions (e.g. butterflies often sit on logs). Although Riches et al. did not find enhanced

Table 9.8

*Overview of involved LGP, EF and other aspects influencing performance in the language task as well as developmental trends for AP and overall performance*

| | Involved LGP | Involved EF | Other factors | Prevalence of AP in ASD<br>RT | <br>ACC | Overall performance<br>RT | <br>ACC |
|---|---|---|---|---|---|---|---|
| AMBWORD | Vocabulary (local) | Inhibition/ Suppression | |  |  |  |  |
| AMBSENT | Local coherence | Inhibitory control | |  |  |  |  |
| SENTORD | Global coherence, Use of local cues | WM, cognitive flexibility | Complexity |  |  |  |  |
| SENTCOMP | Response style / preference | Inhibition, response monitoring | Implicitness | | |  | |

*Note.* AP: Atypical performance. Graphs indicate prevalence for AP and quality of performance (higher performance = lower RT, higher ACC).

local processing in their ASD sample, this task would have been a beneficial addition to the current test battery offering the direct examination of local processing (also in contrast to local coherence in AMBSENT).

The current results in AMBWORD and AMBSENT revealed intact (although slower) LGLP in participants in ASD. There is evidence that performance in this clinical group can vary, depending on whether the stimulus material is presented auditorily (recorded like in the current study) or visually (so participants have to read the words/sentences): for example, Chahboun et al. (2016) found poorer performance of figurative language when stimuli were presented auditorily compared to visually, whilst Mostert-Kerckhoffs, Staal, Houben, and de Jonge (2015) showed that ASD had more difficulties with response inhibition and flexibility when information was presented auditorily compared to visually. The current findings are therefore not transferable to other domains. It would have been interesting to examine whether presentation of stimuli in different modalities in the current task influenced results.

## 9.4 Conclusion of Chapter 9

The investigation presented in this chapter showed similar results in TD and ASD regarding processing of local and global language aspects; thus, giving little support for the WCC theory, although a higher percentage of individuals with ASD showed a local response style in SENTCOMP. Overall, the ASD groups performed poorer considering RTs and accuracy and a detailed examination lead to the conclusion that performance in ASD was likely impacted by subtle deficits in various aspects of EF. The analysis of the prevalence of atypical performance in the clinical group revealed specific developmental trends that allowed to deduct trajectories for the overall performance. They were interpreted indicating developmental delay with deficits being present already in children, which, depending on the measure in question, either persisted, became larger or smaller with age.

The literature review in Chapter 4 revealed that deficits in global language processing in ASD are usually attributed to either weak central coherence (e.g. Vulchanova et al., 2012), reduced general language abilities (e.g. Norbury, 2005) or deficits in EF, especially in inhibition (e.g. Henderson et al., 2011). The account that poor contextual processing is associated with general language difficulties was not investigated in this chapter. Although the evidence points towards high involvement of a range of EFs in LGLP, the possibility of overall language skills influencing performance is not low. For example, we reported that in the task SENTCOMP the CS and RTs correlated with VP in TD but not ASD.

In the next chapter, the relationship between LGLP and language ability will be examined in a correlation analysis. Further, addressed will be the question whether LGP in language is associated to LGP in vision. Lastly, as the analysis of the relationship between LGP in vision and individual differences like autistic traits showed a significant correlation in TD, it will be examined whether or not this relationship can also be found in language.

# 10 Individual differences and local and global processing within and across domains

In ASD research, impaired performance on global language tasks has previously been attributed to impaired suppression/inhibition of irrelevant information and thus deficient EF (Henderson et al., 2011), weak central coherence (Jolliffe & Baron-Cohen, 1999, 2000; Vulchanova, Talcott, Vulchanov, & Stankova, 2012; Vulchanova, Talcott, Vulchanov, Stankova, et al., 2012), reduced language abilities in general (Brock et al., 2008; Brown et al., 2013; Gernsbacher & Pripas-Kapit, 2012; Norbury, 2005a), and developmental delay (Chahboun et al., 2016; Vulchanova, Talcott, Vulchanov, Stankova, et al., 2012, cf. literature review in Chapter 4). Bavin et al. (2014, but see Hahn et al., 2015) found that language ability did not influence language processing abilities in an eye-tracking study, but symptom severity did (as measured by the AQ, Baron-Cohen et al., 2001). In vision, autistic traits have previously been shown to be associated with processing biases (see meta-analysis by Cribb et al., 2016, and the results in the VISTA study, Chapter 8). Thus, potentially, greater prevalence of autistic traits could also be related to more local/less global processing in language. This was examined by correlating the performance indices in the language tasks with the scores on the AQ.

In Chapter 8, we examined different aspects of LGP in visual perception throughout development. As the same participants had been assessed in the visual and language tasks, this allowed for an investigation on whether and how LGP in language and vision were related to each other, for example, whether participants who had a local processing bias in the hierarchical figures task also tend to give more local completions in SENTCOMP, or whether both domains were independent of each other. Thus, the domain-independence of processing styles was examined.

The above topics were addressed by means of a correlation analysis between a simple measure for VP (WASI Vocabulary task, Wechsler, 1999), a measure for autistic traits (AQ) and a selection of variables from the language tasks and visual tasks. The correlation analyses had two goals:

1) To determine whether poorer global processing was associated with a) a higher proportion of autistic traits (while controlling for age and language ability) or b) poorer overall language ability (while controlling for age and autistic traits), thus indicating a potential reason for reduced global processing in ASD.
2) To determine whether LGP indicators from different language and visual tasks were associated with each other, thus examining the notion of task- and domain-overarching processing styles.

## 10.1 Analysis

The following variables were selected from each task as indicators for local or global processing:

Overall accuracy in AMBWORD and accuracy in the temporal condition in SENTORD were selected as indicators of local processing. These measures were found to be discriminative of different conditions in previous analyses (Chapter 9). Higher values indicated better performance in local aspects of language.

For global processing, in AMBSENT the $CSR_{ACC}$ for subordinate meanings was selected as it indicated the amount of contextual processing in the most challenging condition (suppression of the dominant meaning of the word, e.g. She met him at a ball → toy ball picture). Further, for SENTORD, accuracy in the coherence condition was chosen. Equivalently to Booth and Happe's correlation analysis (2010), the CS from SENTCOMP was included. Higher values on these measures indicated better performance in global aspects of language.

Further, the Bias Indicators (BI) from two blocks from the visual tasks from the VISTA study served as indicators for local and global visual processing: The $BI_{RT}$ from the G20L80 block (20% global, 80% local targets) indicated a local processing advantage: the higher the $BI_{RT\text{-}G20L80}$, the more local bias the participant exhibited in this locally biased block. For global processing, the inverse of the $BI_{RT}$ from the globally biased G80L20 block (80% global, 20% local targets) was chosen so that higher values signified more global bias (instead of lower values).

Zero-order parametric correlations I between measures were calculated as well as partial correlations (*pr*) to show how the relationships were affected by removing the effects of age, language scores and/or AQ scores. In order to correct for multiple comparisons, a stricter significance level of $\alpha = .01$ was chosen. All participants (TD and ASD) were analysed together. See Appendix I for a comprehensive correlation matrix.

## 10.2 Results

### 10.2.1 LGP and autistic traits

The analysis revealed a weak significant correlation between the SENTCOMP CS and AQ scores ($r = -.34$, $p < .01$) which increased slightly once age was controlled for ($pr = -.41$, $p < .01$): lower completions scores went along with higher AQ scores.

Significant was also the weak correlation between the AQ and accuracy in the temporal condition of SENTORD when age and VP were controlled ($pr_{\text{age \& VP}} = -.26$, $p < .01$). This was mainly carried by the ASD group ($r = -.31$, $p < .05$; TD: $r = -.04$, $p > .05$). Higher AQ scores went along with lower accuracy. Further examination showed that accuracy in the coherence condition was also negatively correlated with AQ in the ASD group ($r = -.32$, $p < .05$, but n.s. with $\alpha = .01$), but not the TD group ($r = .17$, $p > .05$).

No other significant correlations between the LGP measures and AQ were found.

### 10.2.2 LGP and language ability

The analyses showed that VP was positively correlated with accuracy in both SENTORD conditions (temporal $r = .27$, $p < .01$; coherence $r = .31$, $p < .001$), also when controlling for age, or age and AQ (temporal both $pr = .34$, $p < .001$; coherence $pr_{\text{age}} = .35$ and $pr_{\text{age \& AQ}} = .34$, respectively, $p < .001$). Thus, the higher the VP, the higher the accuracy in the SENTORD task. Further examination showed that this relationship was absent (n.s.) in TD ($r$ and $pr < .28$), but low to moderate and significant in ASD (temporal $pr_{\text{age \& AQ}} = .44$, $p < .01$; coherence $pr_{\text{age \& AQ}} = .54$, $p < .001$).

The measures from the other language tasks were unrelated to VP ($p > .05$).

### 10.2.3 LGP within and across domains

The accuracy measures in AMWORD and both conditions in SENTORD showed moderate, but highly significant correlations, even when age, VP and AQ were controlled ($pr = .45$, $p < .001$), irrespectively of whether they were classed as a local or global task. Other correlations were either nonsignificant or did not meet the stricter α-level of .01.

No significant correlations were found between the visual BIs and the language measures ($p > .05$). Only a tendency for a weak positive correlation was found between the CS and a local bias which persisted when age, VP and AQ were controlled ($pr_{\text{age, VP \& AQ}} = .30$, $p < .05$), indicating a more global language style going along with more local visual bias. This relationship was absent in the global visual task.

## 10.3 Summary and Discussion

### 10.3.1 LGLP, autistic traits, and language ability

The first question addressed was whether LGP in language was affected by individual differences in the participants' the amount of autistic traits and language abilities.

The correlation analysis gave some evidence for a relationship between AQ and LGLP: Participants with higher AQ scores had lower CS, thus a more local response style in SENTCOMP, although the relationship was only weak. Given that this relationship was to a larger extent influenced by the ASD participants (N = 50) than the TD participants (N = 16), this could be interpreted as a more local response style with higher severity of ASD. Further, higher AQ scores were associated with lower accuracy in the SENTORD task, especially in the ASD group where the effect was present for both conditions, indicating lower overall performance on that task in more affected individuals with ASD; but yet again, the relationship was very weak.

Similarly, when assessing the correlations between VP and LGLP, higher VP went along with higher accuracy in SENTORD (especially in ASD), but VP was not related to the AMBWORD, AMBSENT or SENTCOMP measures. Thus, although some evidence was found for the notion that poorer language abilities were associated with poorer global processing, this relationship was also found in the (local) temporal condition of SENTORD. It thus indicated simply that performance in more complex tasks relied more on verbal abilities, independently of the processing level.

The language and AQ scores had to rely only on single variables: The WASI Vocabulary T-score served as the VP measure, whereas the AQ total score served as the autistic traits measure. The WASI Vocabulary task is a rather crude measure for VP; thus, the current results must be interpreted with caution. Unfortunately, not all TD participants completed the Children's Communication Checklist (CCC) or Communication Checklist for Adults (CCA) which could have provided more detailed information about language skills as well as autistic traits as they include scales for structural language competence as well as for pragmatic skills.

Furthermore, we assessed TD and mostly highly verbal ASD, not language impaired individuals (the T-scores for VP ranged between 38 and 80), and both groups showed generally good performance on the language tasks. A larger variability in the data, e.g. by including controls samples with diagnosed LI (with and without ASD) could have allowed for more meaningful conclusions. For example, Norbury (2005) tested four groups with/without ASD and with/without LI on the AMBWORD and AMBSENT tasks and found reduced use of context in the LI groups but not those without LI (while Riches et al, 2016, who also had such four samples, found effects of neither ASD nor LI). We argued that AMBSENT was a local coherence task (Jolliffe and Baron-Cohen, 1999). Thus, the current participants with ASD were not expected to perform poorly. The fact that VP was associated with performance in the SENTORD task is not surprising as higher vocabulary knowledge would help with understanding the sentences and being able to order them correctly. For example, a few children asked for definitions for "foundations" or "ornaments". The relationship between VP and accuracy was stronger in ASD; potentially, remembering the new definition while also keeping the five sentences in WM in order to arrange them correctly, could have posed higher cognitive demand on the ASD group which lead to reduced accuracy. Those with higher symptom severity (as measured by the AQ) might have been affected more by the increased WM requirements, thus lowering their performance accuracy. As discussed in Chapter 9, WM deficits in ASD have consistently been reported in previous research (see review by Kercood, Grskovic, Banda, & Begeske, 2014; and meta-analysis by Wang et al., 2017).

In sum, the analyses showed that there was little evidence for VP being related specifically to global language processing; in fact, a relationship of VP was found to both processing levels which reflected rather the increased complexity of the tasks instead of level-specific mechanisms. The correlations could have been mediated by WM performance. With increased amounts of autistic traits (and thus, symptom severity in ASD), participants showed a more local response style on the SENTCOMP task. As was discussed in Chapter 9, poor performance on this task could also be related to reduced EF, including response monitoring, and the implementation of compensation in more able individuals.

### 10.3.2 LGP across language measures and across domains.

The LGLP measures did not show much association with each other: only those that were pure accuracy measures (AMBWORD, SENTORD) correlated irrespectively of whether they represented local or global processing, showing that participants who performed well in one task, did so also in other tasks. There was also no significant relationship between the language measures and visual processing biases with only a tendency of a more local bias in vision with a higher CS. Overall, there was little evidence for a domain-overarching cognitive style.

Pletzer et al. (2017) demonstrated in their study that the same participants sometimes showed a local, sometimes global processing style and that it depended on the stimuli or task. There was no general tendency in individuals towards a particular style which is in line with the missing relationship between measures in the current study. The lack of correlation or trade-offs between performances in different LGP tasks within and across domains have also been reported elsewhere (Chamberlain et al., 2017; López, Leekam, & Arts, 2008; Milne & Szczerbinski, 2009; Van Eylen et al., 2018).

## 10.4 Conclusion of Chapter 10

To conclude, the correlation analysis found that AQ scores and verbal abilities were negatively related to overall accuracy in the more complex task SENTORD but not the simpler language tasks. Higher prevalence of autistic traits was also associated with a more local processing style in SENTCOMP. These findings, which were more prevailing in ASD, were interpreted as potentially being mediated by deficits in EF in the clinical group.

Lastly, there was no evidence for a task- or domain-overarching cognitive style in TD and ASD participants.

# 11 General Discussion

Seventy-five years since Leo Kanner's first description of 'infantile autism' in 1943 and three decades since Uta Frith's seminal weak central coherence theory (WCC, 1989), research into information processing in ASD is still going at full speed. Nearly every published study appears to conclude with more open questions than it started with, and new theories are developed every year trying to explain inconsistent research. This current research set out with the aim clarify some of the inconsistencies by conducting a comprehensive investigation into local and global processing (LGP) in TD and ASD. The aims were to examine why there are many different and contradicting results regarding LGP (PECOG study), to determine developmental trajectories in TD and ASD for visual and language processing (VISTA and LANTA study) and to investigate whether processing styles are stable within and across modalities. Lastly, this programme of research aimed to evaluate the applicability of prevalent theories to explain LGP in ASD.

This chapter will present and discuss the key findings from four experimental chapters addressing the aforementioned aims.

## 11.1 Examination of aspects influencing LGP in TD in the visual domain (PECOG Study)

In chapter 7, the PECOG study was presented which included three visual experiments with TD students examining the influence of stimulus characteristics on the global precedence effect (GPE or global bias) in a hierarchical figures task; further, the flexibly of the bias by a manipulation of the contingencies of local and global trials, and the influence of reduced processing times on LGP. The main finding was that the TD adults showed a global bias in all three experiments. In the first experiment, the bias was largely independent of stimulus characteristics like type of geometrical form, number of elements, stimulus fill/outline; it was, however, more pronounced in smaller stimuli compared to larger ones and there was no bias with some of the filled in stimulus sets. The second experiment manipulated the amount of local and global trials in each experimental block, ranging from 100% local targets to 100% global targets in order to examine the malleably of the global bias. Participants' biases changed significantly depending on the contingencies in each block and they showed, for example, even more global bias in the globally biased G80L20 block but lower RTs to local targets in the locally-biased G20L80 block. However, this contingency effect (CE) was less pronounced on the local level. The possibility that the CE was based on automatic/implicit processes like level- and identity-priming was examined. Although priming effects increased with higher contingencies, there seemed to also be a voluntary/strategic component to the CE. The third experiment demonstrated that although the bias could be shifted to the local level, this shift was less stable and could more easily be disrupted by occasional targets on the global level (while the effect was not found in reverse), especially when processing times were reduced by the masking stimulus. Masking also impacted processing on local targets directly by reducing the accuracy of the responses on that level, probably because in contrast to the global level, processing on the local level was not yet sufficiently completed before it was interrupted by the masking stimulus.

Researchers have proposed that the source of the GPE could be either a sensory mechanism (temporal processing advantage of low spatial frequencies compared to high spatial frequencies (e.g. Lamb & Yund, 1996; Robertson, 1996; although Dale and Arnell (2014) recently demonstrated that special frequencies and processing biases rely on relatively independent processes), a perceptual or perceptual-organisational process (e.g. Kimchi, 1992; Kimchi, 1998; Paquet & Merikle, 1984) or a post-perceptual process (supported by the fact that attention can modulate the bias, e.g. Plaisted, Swettenham, & Rees, 1999). Here, it was argued based on the PECOG results that the GPE has perceptual aspects (influence of certain stimulus characteristics, identity-priming), and cognitive/strategic aspects (level-priming, CE) which influenced LGP.

The PECOG study demonstrated clearly that a global bias in TD was prevalent and strong, not only in regards to general perception but also in regards to the higher adaptability of the bias with increasing contingencies and the imperturbation of the bias through reduced processing times. We added to the evidence of size and stimulus fill affecting LGP which has previously been reported by other researchers (e.g. Hübner & Kruse, 2011; Lawson et al., 2002; List et al., 2013; Wang et al., 2007) and demonstrated yet again, that studies using the same task (hierarchical figures task) but different stimulus sets and task parameters need to be compared with caution. The study further validated the hierarchical figures paradigm and stimulus sets which allowed for their use in the larger developmental studies (VISTA and LANTA in Chapters 8 to 10).

## 11.2 Examination of the development of visual LGP in TD and ASD (VISTA Study)

In the VISTA study in Chapter 8, 68 TD participants aged 7 to 52 years as well as 50 participants with ASD aged 8 to 54 years were examined. Five different blocks of the hierarchical figures task were implemented with the aim to examine how LGP develops in the typical and clinical groups, whether and how stimulus presentation times, contingency manipulations/priming, as well as interindividual differences in the amount of autistic traits, influenced LGP.

Although there were no obvious developmental trends, a more in-depth analysis revealed subtle differences between age groups and samples. In terms of TD, all participants exhibited a global bias and CE, although there was a tendency for more global bias and a reduced CE in children who also showed the highest costs when switching between processing levels. Interestingly, the negative effect of masking on accuracy on the local processing level that was found in PECOG was not replicated in the adult sample of the VISTA study; instead, a trend for the effect was found for children. Long stimulus durations led to less global bias in children with a tendency of a local bias. There was a local processing preference in at least some children, although their more automatic/involuntary processing was directed to the global level (as shown by the performance with shorter stimulus durations).

Strikingly, the participants with ASD also had a global bias (and not a local bias as could have been expected based on the literature and well-established theories like the WCC). The analysis of the ASD data pointed towards a developmental delay in this group in a number of aspects: First, like TD children, the ASD participants showed a less distinct CE for accuracy on the local level, which could indicate reduced cognitive flexibility in those groups, especially on the non-default level (here local). ASD children also had a slightly less pronounced CE than TD children (as differences between the biases in blocks with increasing contingencies were not significant). Second, in children and all ASD groups, switch costs were higher when switching from local to global than vice versa (while they did not differ in older TD groups), which can be interpreted as either a selective deficit in the broadening of the attention spread (Mann & Walker, 2003), or a problem with the inhibition of local information in those participants (Katagiri et al., 2003). Although the ability to shift biases appeared overall relatively similar between TD and ASD, it was suggested based on previous research that underlying processes might differ and be more cognitively taxing in ASD (Cowan et al., 2010; Iarocci et al., 2006; Richard & Lajiness-O'Neill, 2015). In sum, although perception biases did not differ much between TD and ASD participants, differences in performance were found which were based on reduced cognitive flexibility in the ASD group in comparison to their peers, and potentially reduced inhibitory control and manipulation of attentional spread. Deficits in inhibitory control and increased interference in ASD have been repeatedly shown by other researchers (see meta-analysis by Geurts et al., 2014).

The examination of the effect of stimulus durations revealed two important findings. TD and ASD had a different response strategy in the blocks MASK and LONG: In MASK, TD participants had a stronger global bias regarding RTs, whereas the opposite was found regarding accuracy where ASD had more global bias. In LONG, participants with ASD responded slower than TD participants, although they showed similar RTs in the blocks with shorter stimulus durations. Thus, the common interpretation that longer RTs indicate higher cognitive demand in ASD does not always apply, as it is unlikely to be the reason for this slowing in performance in the least challenging block. Rather, the ASD participants might have been less aware of the need to respond fast (potentially due to not adhering to the given instructions as much as the TD group). Together, results of the variation of stimulus durations and its effects encourage—yet again—a cautious comparison of studies with different task parameters.

## 11.3 Examination of the development of LGP in language in TD and ASD (LANTA Study)

The same participants that were assessed in the VISTA study also completed the LANTA study (Chapter 9) which examined local and global processing in tasks with increasing 'globality' ranging from a single words picture verification task (AMBWORD) to a relatively complex sentence ordering task.

The results in the AMBWORD and AMBSENT tasks showed that suppression of irrelevant meaning/inhibitory control developed with age for TD, as did the benefit of local cues and the general ability to manipulate information (an aspect of working memory) in the SENTORD task. Similar developmental trends were observed in the ASD group, however with a developmental delay compared to TD.

In ASD, performance was slower in the language tasks than in TD while the prevalence of atypically slow performance (AP) even increased with age in the AMBWORD task indicating increasing developmental delay in ASD with age in this task. This was surprising, given that AMBWORD was classed as a local task and should, according to theory, represent a relative strength in ASD. In SENTORD, performance patterns between TD and ASD did not differ much, although the ASD groups performed significantly slower and less accurately than their peers. The prevalence of AP in AMBSENT and SENTORD decreased with age, thus showing that some participants with ASD caught up with their TD peers by the time they reached adulthood. It was suggested that the complexity of the SENTORD task posed higher cognitive demand on WM in ASD participants leading to slower and less accurate performance (Koolen et al., 2014; Koolen et al., 2013, see also review by Kercood et al., 2014). This was particularly evident in some participants who performed in ceiling in the less complex tasks, but in the range of atypical performance in SENTORD. Although, to our knowledge, examinations of developmental trajectories of WM in ASD are still missing, the data suggest that WM capacity increases with age not only in TD (Brockmole & Logie, 2013) but also ASD.

AMBSENT, a local coherence task, and SENTCOMP, a task to unveil processing preferences, both involved contextual processing of single sentences; however, the difference was in the explicitness/implicitness of the tasks. While AMBSENT was an explicit task where participants were made aware that there were correct and incorrect responses and their RT and accuracy was measured (“Respond as fast as possible without making mistakes”), SENTCOMP was open-ended and participants were asked to just “say something to finish the sentence”. Researchers have previously demonstrated that ASD participants showed more deficits in implicit tasks compared to explicit ones, probably as response monitoring and compensation strategies are not as readily applied in implicit tasks (Hala et al., 2007; Henderson et al., 2011; Van Eylen et al., 2011; Van Eylen et al., 2015). The current ASD participants and the very limited TD sample, both showed that the prevalence of a local response style in SENTCOMP reduced with age, i.e. older participants exhibited a more global style, possibly due to increased skills in monitoring and compensation. There were more ASD participants in each age group that showed a local style, potentially due to reduced skills compared to their peers. The finding of decreasing prevalence of local response styles replicated Booth and Happe’s (2010) results.

Altogether, the LANTA study demonstrated that processing on LGP tasks follows a delayed developmental trajectory, although in most measures the difference between TD and ASD reduced with age. Importantly, we do not claim that local *or* global processing was impaired or delayed, but that the findings in this investigation represent overall, level-independent deficits. The underlying dimension for those deficits appear to be EF and its various aspects, including WM, cognitive flexibility, response monitoring and inhibitory control/suppression.

## 11.4 Examination of processing styles within and across domains and their dependence on interindividual differences

The research presented in Chapter 10, investigated the relationship between LGP measures and the individually varying amounts of autistic traits (as measured by the AQ) and varying VP (as measured by the WASI Vocabulary task).

It was found that only accuracy in the most complex task (SENTORD) was associated with VP and also with AQ: individuals with higher VP, and those with lower AQs, performed better, independently of whether it was the global or local condition. Interestingly, this relationship was mainly observed in the ASD group. This speaks against the WCC theory, according to which individuals with ASD (i.e. per definition those with high AQ scores) would show deficits in the global relatively to the local condition, but gives limited support for the notion that individuals with ASD struggle with global language processing due to underlying general language difficulties (Norbury, 2005). As was discussed in Section 9.2.5.2, it could be argued that at least some stories in the temporal condition did require not only attention on local cues but consideration of the total story gist in order to order the sentences correctly. Thus, the local condition might have been confounded with global processing requirements.

In terms of autistic traits, the AQ was related to the CS in SENTCOMP, indicating a less global response style with higher amounts of autistic traits (supporting the WCC) which is in accordance with previous research from the visual domain (e.g. Crewther & Crewther, 2014; Cribb et al., 2016; Grinter et al., 2009; Van Boxtel & Lu, 2013). The relationship between AQ and visual processing was investigated in the study presented in Chapter 8 (VISTA study) and found interesting results. In TD (but not ASD), higher AQ scores went along with more global bias in adults which is in contrast to the cited literature as well as our results in the language study (LANTA, Chapter 9). Based on those findings in the TD group, it was hypothesised that individuals with ASD might also show a global instead of local bias in the hierarchical figures task, which was, indeed, confirmed later on. It was suggested that the relationship between AQ scores and global bias for the current task was positive up to a certain amount of autistic traits (e.g. around the clinical cut-off scores) and then levelled out. To our knowledge, studies assessing correlations between AQ scores and LGP across TD and clinical samples are rare—only one study by McKenzie et al. (2018) could be identified. Therefore, further research, ideally with larger sample sizes (especially children which were underrepresented in this analysis) could address this hypothesis.

The examination of the relationship of LGP measures within the language domain and also between the language and visual domain showed no evidence for overarching processing styles or trade-offs between local and global processing. It seems, therefore, that processing styles in different tasks and domains are independent of each other, and that individuals, especially older ones, choose the most appropriate one for a given task (called ‘good adapters’ by Booth, 2006, in contrast to ‘poor adapters’; Evans et al., 2013; Happe & Booth, 2008; Happe & Frith, 2006; Huizinga et al., 2010; Niaz, 1987; Pletzer et al., 2017); thus, they sometimes show a local, sometimes global processing style. Our visual experiments in VISTA support this, as the participants were able to shift their attention to the local or global level (despite the default-level being global) depending on the contingencies in the task.

## 11.5 Evaluation of the applicability of prevalent theories to explain LGP in ASD

In the literature review presented in Chapter 4, different reasons were presented to explain why individuals with ASD might show deficits in global visual and language processing: reduced overall language abilities (Section 4.4.6.2), weak central coherence (Section 4.4.6.3), and deficits in the EF inhibition (Section 4.4.6.4).

The weak central coherence theory (WCC, Frith, 1989; Happe & Frith, 2006) states that individuals with ASD have a reduced tendency to process information in its context and, instead, show a local processing advantage/local cognitive style, which is apparent, for example, when processing ambiguous words in sentence contexts (similar to the task AMBSENT) or geometrical forms in hierarchical figures (like in the VISTA study). However, other researchers have argued that processing of single sentences should be classed as local coherence and could, therefore, pose a strength in ASD in comparison to global coherence which involves five or more sentences (like in SENTORD, e.g. Jolliffe & Baron-Cohen, 1999; 2000, see literature review in Section 4.4).

Norbury (2005) advocated a different reason for poor performance of ASD participants in language tasks requiring contextual processing: general underlying language difficulties. She supported this with evidence from her study including individuals with/without ASD and with/without language impairment (LI) demonstrating that those groups with LI (LI +/- ASD) performed similarly poor and those without LI (ASD-LI, TD) performed similarly well on the ambiguous words task that was also used in the current study (AMBSENT).

The inhibition deficit theory proposes that language comprehension is reduced in ASD due to deficits in the inhibition of irrelevant information (Henderson et al., 2011) which would be relevant, for example, for the performance in AMBWORD and AMBSENT. Fittingly, Norbury (2005) acknowledges that deficits in the tasks utilised in her study might be based on impaired inhibition. Inhibitory control falls under the umbrella term executive function (EF) which also encompasses the other two core functions cognitive flexibility and working memory (Diamond, 2013).

This thesis argued that performance on the tasks implemented in this investigation was heavily influenced by the core aspects of EF and not (just) local and global processing:

- Inhibitory control: relevant for suppressing irrelevant meanings in AMBWORD and AMBSENT and potentially more automatic (local) responses in SENTCOMP.
- Cognitive flexibility: relevant for shifting between processing levels and flexibly adjusting perception biases in the VISTA study.
- Working memory: relevant for holding five sentences in memory and rearranging them in SENTORD.

It was further suggested that the implicit nature of the SENTCOMP task prevented response monitoring and the use of compensation strategies in some participants (especially younger ones with less sophisticated EFs) who might have used those in the other more explicit tasks (cf. overview inTable 9.8 on page 247), leading to the finding of reduced use of context in ASD/a less global style.

In accordance with the results of this investigation, Happe and Frith (2006) acknowledged in their review that many findings supporting the WCC theory could potentially be explained by difficulties in EF, e.g. reduced shifting abilities, limitations in WM and poor planning. Their conclusion that a local bias in ASD was not due to executive dysfunction was based on only three experimental studies (Booth et al., 2003; Teunisse et al., 2001), one of which did actually have evidence for EFs being a significant factor (Pellicano et al., 2006). The current investigation does not claim that deficits in EF explain processing in ASD better than the WCC or LI theory; rather that EF appears to be a significant common factor influencing performance on all our tasks. The results from three out of four of the language tasks and the visual tasks did not reveal reduced global and/or enhanced local processing in ASD and thus, did not support the WCC. In favour of the WCC, there were some indications that local coherence might be a strength in ASD (as interpreted from the results in AMBSENT, see Section 9.2.4.2) as well as that individuals with ASD were more likely to show a local processing style although this was the case for less than 1/3rd of the ASD sample (in SENTCOMP).

The findings of this investigation did not contradict the theory of underlying language difficulties as a reason for poor global processing. However, they also did not support it fully which was not surprising, given that no individuals with actual language impairment were assessed. We included mostly highly verbal individuals with VP T-scores of 42 to 80 in the TD groups and 38 to 80 in the ASD groups. The finding of the positive correlation between VP and accuracy in SENTORD is in favour of the language difficulty theory, however, those correlations were firstly present for the global as well as the local condition (thus, poor language is not just associated with impaired global processing) and secondly, they were higher in ASD participants than those with TD; thus, likely moderated by another aspect unique to ASD, which, as was argued, could be reduced EF in ASD.

EFs have long been in the focus of interest when explaining symptoms of individuals with ASD: from the first appearance of the executive dysfunction theory (Ozonoff et al., 1991) to very recent meta-analyses (e.g. Demetriou et al., 2017; Van Eylen et al., 2017; Wang et al., 2017). We argue that deficits in EF could explain many of the findings regarding LGP in ASD not just in our research, and recommend to include measures for EF in future studies in order to evaluate their involvement in the research outcomes.

## 11.6 Methodological considerations, limitations and recommendations for future research

One might argue, that the reason for a lack of global processing deficits in ASD in this study is that the tasks that were selected for the assessment of local and global aspects of language, did, in fact, not measure what they were supposed to measure, thus, questioning their validity. This is a controversial argument which resonates with Brock and Bzishvili's (2013) critique of the homograph reading task; the task is often seen as the gold standard measure for central coherence just "*because autistic individuals perform poorly*" (p. 1765). Brock and Bzishvili demonstrated that many other factors influence performance on that task: interference from previous trials, the eye-to-voice span and comprehension monitoring. *Local* and *global* are not strictly defined categories and a common conceptualisation or operationalisation of the terms does not exist. Even standard measures for LGP (e.g. homograph reading task, hierarchical figures task, embedded figures tasks) have been shown to measure different aspects of performance, including disembedding, global bias, cognitive flexibility, and perceptual speed  (see meta-analyses by Chamberlain et al., 2017; Milne & Szczerbinski, 2009; Van der Hallen et al., 2015). The operationalisations of the constructs *local* and *global* in the current investigation were formed after the consideration of a wide array of literature (see e.g. Section 4.4 and especially Figure 4.1 on page 61) and the selected tasks were based on previous studies, most of which have previously found significant deficits in ASD (if not in the same tasks then in similar ones). We would, therefore, argue that the implemented tasks were valid tasks in light of how local and global processing were defined in this research.

There were further limitations in this investigation which should be considered in future research projects. This investigation set out with the aim to examine local and global processing in perception and language, its development and whether processing styles were overarching modalities. Thus, the aspect of EF was not in the centre of interest. However, EFs were interpreted as a central factor in the current results but this conclusion needs to be tested in further research. Ideally, separate measures for different aspects of EF would have been applied in this investigation, including those that measure a) inhibitory control, b) working memory, c) cognitive flexibility/set-shifting. Doing so in a cross-sectional study poses certain challenges; for example, as Petersen, Hoyniak, McQuillan, Bates, and Staples (2016) point out in regards to inhibitory control, tasks might only be useful for an age range of less than three years if ceiling and floor effects are to be avoided. Van Eylen and colleagues (Van Eylen et al., 2017; Van Eylen et al., 2015) applied a large battery of EF measures covering inhibition, cognitive flexibility, generativity, spatial working memory, planning and daily life EF in 50 individuals with and without ASD aged 8 to 19 year old (2015), as well as over 100 relatives of individuals with ASD and 100 TD controls aged 8-18 and 30-60 years old (2017). Unsurprisingly, age effects were found in nearly all assessed variables. More specific recommendations for future research involving EF will be discussed in Section 11.6.1.

Related to the point above, the current implemented LGP tasks were relatively easy, particularly for adolescents and adults. This allowed for a good analysis of the RT data but it also limited the meaningfulness of the accuracy data as most older participants performed at or close to ceiling in the majority of tasks. Although more challenging tasks could have been chosen to avoid this, this solution would have been suboptimal, as consequently, children could have been overwhelmed, thus producing poor data. Alternatively, different more-age appropriate tasks could have been implemented but it this would have in turn limited the comparability of the data across age groups.

The current TD sample was relatively small for a normative sample. A larger sample of 200+ TD participants (like e.g. in Booth, 2006) would have been desirable. This would have also permitted to analyse the data with a regression approach. A larger, more representative sample could have also clarified and strengthened some of the results and conclusions in this study. Some effects that were found in the VISTA study were only on the margins of significance ($.1 > p > .05$), especially in the child participants.

The matching procedure of the ASD and TD groups had limitations. The groups were matched only on age. Although gender ratio and IQ-scores did not differ between the TD and ASD adolescent and adult groups, they did in children. Ideally, the TD and ASD groups would have been also matched on gender and IQ, possibly with a verbal mental-age matched group and a nonverbal mental age-matched control group (like in Iarocci et al., 2006). McKone et al. (2010) argue that even race can impact on LGP and should thus be held constant or used as a grouping variable in LGP research. Given that the child groups were only comparable regarding age, they could have been analysed separately with IQ and gender as covariates. However, researchers (Dennis et al., 2009; Facon, Magis, & Belmont, 2011; Jarrold & Brock, 2004) have argued against the use of IQ as a covariate or matching variable in neurodevelopmental research. According to them, IQ does not fulfil the criteria of a covariate which often leads to violated assumptions in the ANCOVA, while matching clinical samples with TD samples on IQ leads to non-representative groups: either the clinical group will have higher IQs than the population with this disorder, or the TD group will have lower IQ scores than the population they should represent, which can lead to regression to the mean. Alternatively, Jarrold and Brock (2004) recommend, for example, to assess a 'relatively large' normative sample for a regression analysis including relevant background variables (e.g. age, IQ) and to determine the discrepancy of each individual with ASD between the expected and observed performance. Future investigations could adopt this approach.

The current investigation did not differentiate between Autism and AS, but other researchers have found differences between those groups, for example, regarding switching abilities (Rinehart et al., 2001) or the use of context in language (Jolliffe & Baron-Cohen, 1999). In the current DSM-5 (American Psychiatric Association, 2013), the distinction between subtypes of ASD has been abandoned. As some of the current participants only received their ASD diagnosis after the introduction of the new DSM, a classification into Autism or AS groups would have been difficult without additional background measures or lengthy diagnostic tests (e.g. the ADOS, Lord et al., 2012).

Related to the previous point, the current ASD group consisted of mainly high functioning individuals which might have reduced the chances to find differences between ASD and TD. Additionally, it limited the generalisability of the results to only HFA/AS. Although low functioning individuals with ASD might have been overwhelmed by the tasks and duration of the study, they could have provided further insight into LGP in ASD. For example, Booth (2006) found that ASD individuals with lower abilities had a more prevalent local processing style and interpreted that those with HFA might be better able to compensate.

A number of participants with ASD had additional diagnoses which could have potentially been treated as a sub-sample (e.g. 8/50 participants also had a diagnosis of ADHD). However, some parents of individuals with only one (ASD) diagnosis reported that the child most probably did have more problems like ADHD but they did not want to put the child through further diagnostic procedures and accompanying stress ("*One diagnosis is enough*"). Therefore, it could not be ruled out that those participants without other official diagnoses aside from ASD really did not have further impairments. Consequently, it was decided to include all participants with ASD in one group. If more background measures and tests had been performed to rule out other comorbidities, a cleaner sample could have been attained.

The implemented measures for verbal and nonverbal performance (WASI subtests vocabulary and matrix) had been chosen due to their convenience and short duration—two important factors when testing children or clinical populations. However, other more thorough measures of the participant's verbal and nonverbal abilities would have allowed for further and more elaborate examination of factors associated with LGP. For instance, more elaborate language background measures would have also allowed for a more detailed and comprehensive analysis of the effect of language ability on LGP. Other studies used, for example, background tests for reading comprehension, receptive grammar, and verbal reasoning (Chahboun et al., 2016), or receptive vocabulary, understanding increasingly complex sentences and recalling sentences (Norbury, 2005). Similarly, co-morbid language disorders were not controlled, but given that the current ASD participants were high-functioning, significant language difficulties were unlikely (and would have been reflected in an inability to accurately perform in the language experiments). Tager-Flusberg (2015) showed that a quick non-word repetition task could successfully detect language impairments in participants with ASD and SLI, which could have been a valuable addition to the current test battery.

Lastly, the current study is a cross-sectional study. Despite the clear advantages of such designs for example in regards of time efficiency, they also have disadvantages, as they only provide a snapshot in time, are not able to establish causality between variables, only relationships, and they can only give indications regarding developmental trends that would need to be validated in a longitudinal design. A longitudinal design could either include a follow-up study with the current child and adolescent participants (e.g. one, three and five years after the first assessments) or a new cohort of participants whose development is followed over a period of years. By analysing the developmental trends in the ASD and TD groups it could be elicited whether the ASD participants develop slower (and reach TD standard later in life; thus, are developmentally delayed) or whether they develop differently/atypically. However, Fountain, Winter and Bearman (2012) examined communication, social and repetitive behaviour development in ASD children (0-14 years) and found six different trajectories which were influenced by intellectual ability, ethnic origin, level of education of the mother and socioeconomic status. Therefore, it would be likely to find not just one trajectory for the development of local and global processing in ASD, but multiple, of which some might represent delay and others atypicality. A larger cohort and inclusion of such background variables in the analysis could clarify the issue of the development of LGP.

### 11.6.1 Outline of a possible future study involving Executive Functions

In order to tests the hypothesis that EF were the underlying factor for differences in performance between the ASD and TD groups in this research, we propose to conduct a vision and language study with a narrower age range that focusses on younger participants who are still developing their local and global processing, language and executive function (ages 8-14 years). Four groups of children would be assessed: one group with individuals with a diagnosis with ASD, and three control groups that are matched on verbal mental-age (vAmTD), nonverbal mental age (nvAmTD), and chronological age (cAmTD) in order to examine in a more stringent way in how far mental abilities are involved in LGP. Background assessments would include the following:

1. The complete WASI (Wechsler, 1999) with two subtests per domain (verbal: vocabulary and similarities; nonverbal: matrixes and block design) in order to use them for the participant matching.
2. The MTA Swanson, Nolan, and Pelham-IV Questionnaire (MTA SNAP-IV, Swanson et al., 2001) for screening for possible ADHD comorbidities in the ASD group and ADHD symptoms in the control groups (with the prospect of controlling for ADHD symptoms which might influence EF).
3. The Childhood Autism Rating Scale - Second Edition (CARS2, Schopler et al., 2010) for assessing the severity of the autism symptomatic in the ASD group and relating it to EF performance.
4. The Behavior Rating Inventory of Executive Function (BRIEF, Gioia et al., 2000) for assessing EF in daily life in addition to the experimental tasks testing EF (see below).

The experimental tasks for LGP would be the same as in the current research. Additionally, tasks for the assessment of EF would be included; more specifically, those examining inhibition/ suppression, working memory and cognitive flexibility.

1. Inhibition: A Go/No-Go task (based on Rubia et al., 2001) in which participants are presented with different pictures (20% bombs, 60% aeroplanes, 20% cars) for 1000ms and are required to press a button when they see an aeroplane square or car (Go), but to suppress the button press if it is a bomb (No-Go). The similarly infrequent Go-trials featuring cars serve as a control measure for non-inhibitory processes like impulsivity or sustained attention (Van Eylen et al., 2015). The less false positive responses participants give, the better their inhibition ability.
2. Working Memory: An N-back task (as described, e.g. in Micai, Vulchanova, & Saldana, 2018, submitted for publication) in which participants are presented with separate stimuli one after the other. They are asked to indicate with button press whether the current stimulus is the same as the one they saw *n* trials ago (1, 2, 3 trials). The higher the n, the more difficult the task, as more information must be retained in working memory. Participants view each stimulus for 500ms and have a further 3000ms to indicate whether or not (yes/no) the stimuli corresponded. The more accurate participants' perform, the better their working memory is.
3. Cognitive Flexibility: The Wisconsin Card Sorting Task With Controlled Task Switching (WCST- WCTS, as described in Van Eylen et al., 2011) is an open-ended task without explicit instructions. By modifying the original WCST, Van Eylen et al. (2011) reduced confounding variables (social demands, working memory, generativity load). Participants are presented with three cards on the computer screen: two on the bottom which correspond in a feature (colour or shape) to the card that is on the top. Participants have to find out the correct sorting rules based on feedback. The correct rule can change at any point, thus participants have to flexibility adapt to the rule change. The less preservation errors and the lower the switch cost RT (switch trial RT minus maintain trial RT), the better the participants' cognitive flexibility.

Based on the current findings and the previously cited literature (e.g. Hala et al., 2007; Henderson et al., 2011; Kasirer & Marshal, 2012; Kercood et al., 2014; Koolen et al., 2013, 2014), it would be expected to find that better performance in the inhibition task correlates positively with performance in the tasks AMBWORD, AMBSENT and SENTCOMP. WM would be predicted to be related to the performance in the SENTORD task. Cognitive flexibility would be expected to be related to performance in SENTORD, as well as switch costs and priming in the visual experiments with hierarchical figures. Further, it would be expected to find lower EF in participants with more ADHD symptoms, more severe ASD and/or poorer overall language abilities. In summary, we would expect to find that EF can explain a large percentage of the variance found in the performance in local and global visual and language tasks in ASD (and TD) participants.

## 11.7 Conclusion

This comprehensive investigation of local and global processing in visual perception and language was the first to examine aspects of LGP with a large battery of visual and language tasks in cross-sectional samples of individuals with TD and ASD covering an age range of 45 years. It allowed the investigation of the effects of variations of stimulus, task and sample characteristics on processing biases and an examination of their flexibilities, to determine whether there were domain-overarching processing styles and to establish developmental trajectories in the typical and atypical populations.

Individuals with ASD are often described as missing the big picture or not seeing the forest for the trees. However, whilst this investigation did not confirm such an atypical local processing bias in this sample of high functioning individuals, neither in the visual nor language domain, it did reveal subtle differences between the performance of the TD and ASD samples. The analysis of those differences pointed towards a developmental delay in the clinical group.

Notwithstanding the methodological limitations of this investigation, a strong argument has been made for executive functions, including cognitive flexibility, inhibitory control and working memory having a principle role in accounting for the between TD and ASD. This is in contrast to the focus in contemporary research on perceptual biases. Perhaps it is time to look beyond the forest and the trees.

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# Appendix

# Appendix A Indicators, Acronyms and Formulae

*Table A.1*

*Performance Indicators with Acronyms, Interpretations and Formulae*

| Name / Acronym | Interpretation | Formula |
|---|---|---|
| **Visual Task** | | |
| Bias Indicator - $BI_{RT}$ and $BI_{ACC}$ | BI = 1 → no bias<br>BI < 1 → global bias<br>BI > 1 → a local bias | $BI_{RT}= RT_{global}/RT_{local}$<br>$BI_{ACC}= ACC_{local}/ACC_{global}$ |
| Priming Effect / Switch Costs – $PESC_{RT}$ and $PESC_{ACC}$ | The higher the PESC, the higher priming effects or switch costs (i.e. the higher the difference between primed and switched trials) | $PESC_{RT} = RT_{switch} – (RT_{level\text{-}prime} + RT_{identity\text{-}prime})/2$<br>$PESC_{ACC} = (ACC_{level\text{-}prime} + ACC_{identity\text{-}prime})/2 - ACC_{switch})$ |
| **AMBWORD** | | |
| Dominant Advantage -- $DAS_{RT}$ and $DAS_{ACC}$ | DAS = 1 → no advantage<br>DAS > 1 → the higher the DAS, the faster/more accurate the responses to dominant meanings compared to subordinate meanings. | $DAS_{RT}$ = RT(subordinate) / RT (dominant)<br>$DAS_{ACC}$ = ACC(dominant) / ACC(subordinate) |
| **AMBSENT** | | |
| Context facilitation ratios -- $CFR_{RT}$ and $CFR_{ACC}$ | CFR = 1 → no contextual facilitation<br>CFR > 1 → the higher the CFR, the more facilitation | $CFR_{RT}$ (dominant) = RT(dominant neutral) / RT(dominant biased)<br>$CFR_{RT}$ (subordinate) = RT(subordinate neutral) / RT(subordinate biased)<br>$CFR_{ACC}$ (dominant) = ACC(dominant biased) / ACC(dominant neutral)<br>$CFR_{ACC}$ (subordinate) = ACC(subordinate biased) / ACC(subordinate neutral) |
| Total Facilitation Scores -- $TFS_{RT}$ and $TFS_{ACC}$ | TFR = 1 → no contextual facilitation<br>TFR > 1 → the higher the TFR, the more facilitation (across dominant and subordinate meanings) | $TFS_{RT}$ = (RT(dominant neutral) + RT(subordinate neutral)) / (RT(dominant biased) + RT(subordinate biased))<br>$TFS_{ACC}$ = (ACC(dominant biased) + ACC(subordinate biased)) / (ACC(dominant neutral) + ACC(subordinate neutral))<br>Or simpler:<br>$TFR_{RT}$ = RT(neutral all) / RT(biased all)<br>$TFR_{ACC}$ = ACC(biased all) / ACC(neutral all) |
| Context suppression ratio $CSR_{RT}$ | The higher (and closer to 1) the CSR is, the better the use of context in order to supress irrelevant meanings | $CSR_{RT}$ (subordinate) = RT(subordinate unambiguous) / RT(subordinate ambiguous)<br>$CSR_{RT}$ (dominant) = RT(dominant unambiguous) / RT(dominant ambiguous)<br>$CSR_{ACC}$ (subordinate) = ACC(subordinate ambiguous) / ACC(subordinate unambiguous)<br>$CSR_{ACC}$ (dominant) = ACC(dominant ambiguous) / ACC(dominant unambiguous) |
| Total Interference Scores $TIS_{RT}$ and $TIS_{ACC}$ | TIS = 0 → no interference<br>TIS > 0 → the higher TIS, the more interference from the irrelevant meanings of the ambiguous words | $TIS_{RT}$ = ((RT(dominant ambiguous) + RT(subordinate ambiguous)) – (RT(dominant unambiguous) + RT(subordinate unambiguous))) / (RT(dominant unambiguous) + RT(subordinate unambiguous))<br>$TIS_{ACC}$ = ((ACC(dominant unambiguous) + ACC(subordinate unambiguous)) – (ACC(dominant ambiguous) + ACC(subordinate ambiguous))) / (ACC(dominant unambiguous) + ACC(subordinate unambiguous))<br>Or simpler:<br>$TIS_{RT}$ = (RT(ambiguous all) – RT(unambiguous all)) / RT(unambiguous all)<br>$TIS_{ACC}$ = (ACC(unambiguous all) – ACC(ambiguous all)) / ACC(unambiguous all) |

| Name / Acronym | Interpretation | Formula |
|---|---|---|
| **SENTORD** | | |
| Temporal Facilitation Score $TempFR_{RT}$ and $TempFR_{ACC}$ | TempFR = 1 → performance was the same in both coherence and temporal conditions TempFR > 1 → performance in temporal condition was better TempFR < 1 performance in coherence condition was better | $TempFR_{RT}$ = RT(coherence) / RT(temporal)<br>$TempFR_{ACC}$ = ACC(temporal) / ACC(coherence) |

# Appendix B Development and Piloting of the Language Tasks

## B.1. AMBWORD and AMBSENT

For the language experiments (AMBWORD, AMBSENT), first the words (WORDASSO) and pictures (PICNAME) had to be piloted; next, the tasks were constructed and piloted (AMBWORD, AMBSENT, SENTORD). Finally the data from the pilot studies AMBWORD and AMBSENT was used for an ITEM ANALYSIS in order to select the most reliable items for the actual language study with children and ASD participants.

### B.1.1. WORDASSO (Word Association)

Question: Which meaning of the homograph (i.e. ambiguous word) is dominant, which one is the subordinate meaning?

Method: 50 undergraduate psychology students were asked to report one word that they associate with each of 62 homographs that had a minimum two meanings (e.g. TRUNK).

Analysis: Every answer of the students to every word were coded for category (e.g. for BALL: TOY (associated words e.g. round, throw) or DANCE (party, music) or other). Some answers could not be categorised as allocation to one category was not possible either because a) the associated word was ambiguous (e.g. SHOWER with associated word WATER; MOUSE → MICE), b) the association was to the verb not noun (e.g. SQUASH → SQUEEZE; MATCH → MIX), c) the association was from a common term (e.g. SHAKE → HARLEM; PUNCH → JUDY), d) the association was irreproducible (e.g. PLANT → COLOUR, DATE → ME), e) the word was a rhyme word (e.g. SHAKE → BAKE; SPEAKER → TIKKA). As a second step the allocations to categories were counted and the relative percentage determined. In most cases the dominant category was brought up in more than 50% of student answers and was at least 20% more frequent than the subordinate category.

Results: Most, but not all ambiguous words had a clear-cut dominance/subordination.

### B.1.2. PICNAME (Picture Naming)

Question: Can the pictures that represent the different meanings of the ambiguous words be clearly identified?

Method: 53 undergraduate psychology students were asked to name 124 pictures (representing two meanings for each of the 62 words). They could use one to maximum 2 words. The pictures were collected from various open sources like Microsoft Clipart, Open Clipart (https://openclipart.org/), and Clipart Panda (http://www.clipartpanda.com/).

Analysis: The answers were scored with 0 (wrong term), 1 (partially correct/close enough) or 2 (correct). For example, for the picture of a NUT, the terms olive and lemon would be scored with 0, acorn with 1 and nut, nuts, hazelnut with 2. The frequencies of codes 1 and 2 for each picture were combined to determine the final *name agreement* percentage.

Results: Most pictures had satisfying unambiguity. 12 pictures had to be exchanged or slightly altered. Those ones were piloted again in a similar way with 10 students.

### B.1.3. Pilot Study: Ambiguous Words (Pilot-AMBWORD)

A pilot study with N = 16 undergraduate students (Age = 21.79 ± 3.45, 3 males and 13 females) was conducted in order to test the language tasks for applicability and to conduct an item analysis for further item selection.

#### B.1.3.1. Stimuli

After creating sentences for AMBSENT (see below) during which numerous homographs were excluded from the study, the remaining 44 words were allocated pictures for three conditions: One picture with the dominant meaning, one with the subordinate meaning and one neutral (not related) picture (from Snodgrass and Vanderwart, 1980). The stimuli were split into two groups of 22 words counterbalanced by *frequency* (based on British National Corpus) and *subjective familiarity* (both given by the programme N-watch (Davis, 2005).

Words were read and recorded by an English native speaker with a neutral accent using the software Audacity 2.0.6 (http://sourceforge.net/projects/audacity/).

### B.1.3.2. Procedure

The procedure was the same as described in Section 6.5.2 A list of the piloted stimuli can be found in Table C.2. Each participant responded in total to 132 trials (44 words x 3 conditions) in 2 blocks. Each block lasted between 60-90 seconds (plus instruction and practice).

### B.1.3.3. Results

The results of the pilot study will only be presented very briefly as the main reason for the pilot study was to validate the paradigm and to perform the item selection.

Overall the dominant meaning had the quickest RT compared to the neutral and subordinate condition, (see Figure B.1). The subordinate meaning had the lowest accuracy compared to the dominant or neutral condition. This was according to expectations.

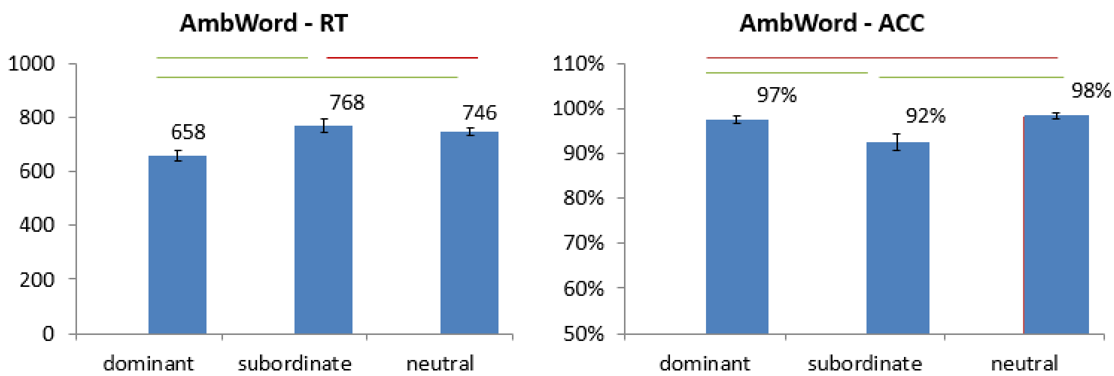



*Figure B.1.* Results of the AMBWORD Pilot Study. Left: RT data. Right: accuracy data. Green lines indicate significate differences ($p < .05$), red lines are n.s ($p > .05$).

### B.1.4. Pilot Study: Ambiguous Sentences (Pilot-AMBSENT)

#### B.1.4.1. Stimuli & Procedure

Please see Section 6.5.3 for a description of the stimuli, conditions and procedure. Each participant responded in total to 352 trials (44 words x 8 conditions) in two separate blocks. Each block lasted between 3 and 5 minutes (plus instruction, practice and breaks).

#### B.1.4.2. Results of the Pilot Study

The Analysis of accuracy and RT revealed that in the facilitation condition responses in dominant trial were more accurate and faster than in subordinate ones, and responses in biased trials were more accurate and faster than neutral ones (see Figure B.2). In the suppression condition dominant and subordinate meanings had the same accuracy and RT, whereas responses in ambiguous trials were slower and less accurate than in unambiguous trials.

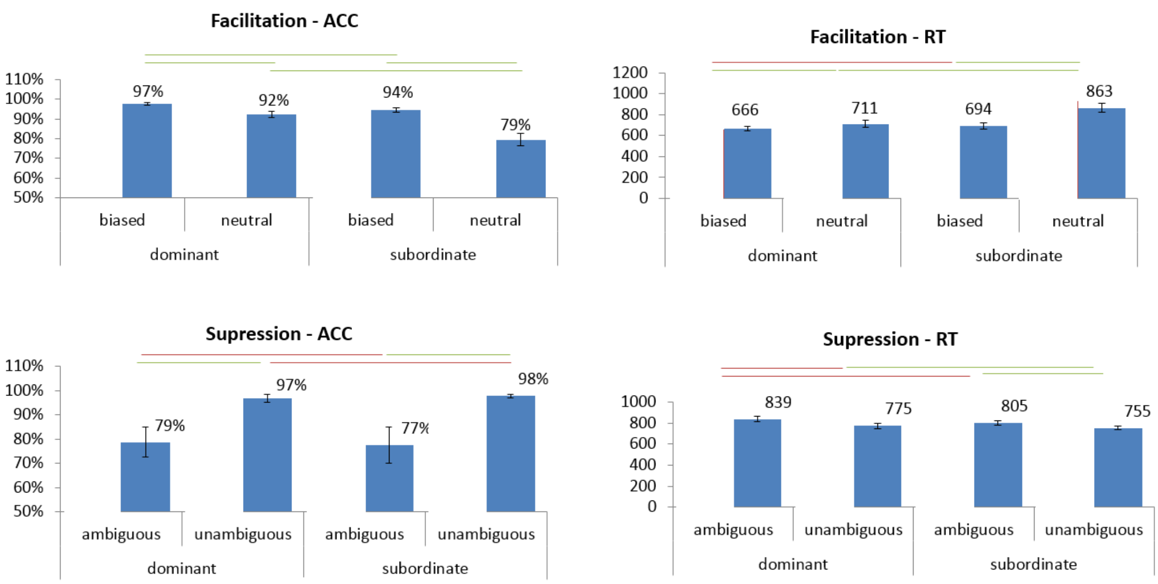



*Figure B.2. Accuracy* (left) and RT (right) results for facilitation (top) and suppression (bottom) condition in the Pilot Study.

### B.1.5. Item Analysis (AMBWORD, AMBSENT)

Based on the data from the pilot study an item analyse was conducted in order to create a smaller selection of the best words.

Descriptives (for RT) and frequencies (for Error Percentage, ERR) for every ambiguous word in both experiments were calculated for all conditions. RT differences ($RT_{diff}$) were calculated between dominant and subordinate meanings in order to examine whether a clear dominance was given. More specifically:

AMBWORD: $RT_{diff}$: The difference between the means/medians of the subordinate and dominant condition were calculated to determine how much faster RTs to the dominant condition were ($RT_{diff} = RT_{sub} - RT_{dom}$). If $RT_{diff}$ was negative, this suggested that the 'dominant' meaning was not dominant but subordinate.

AMBSENT: $RT_{diff}$: The differences between the RTs to the dominant and subordinate picture meanings in the neutral sentence condition were calculated ($RT_{diff} = RT_{neu\_sub} - RT_{neu\_dom}$). Positive values showed good dominance of the meaning.

19 Items were removed from the stimulus set based on the following REMOVAL CRITERIA:

1. If $RT_{diff}$ was negative in AMBWORD and AMBSENT, this was interpreted as wrong dominance coding and it was re-coded with the reverse dominance (DECK, KEYBOARD, NAIL, BAT).
2. If $RT_{diff}$ was negative for one task but positive for the other, this was classed as too ambiguous dominance and the item was removed. (MOLE, COACH, HORN, CHEST, SHAKE, BAR, ORGAN, SQUASH, PUNCH, TOAST, CRANE, PUPIL).
3. If ERR was more than 25% on subordinate meanings (AMBWORD) or 45% for subordinate meanings following neutral sentences (sub_neu in AMBSENT) the item was removed (STRAW, PLANT, FILE, SEAL, TICK, KID).
4. If dominance was too small ($RT_{diff}$ <50ms) the item was removed (CHEST).

The following 25 items remained in the temporary stimulus set:

BALL, BANK, BAT, BOW, BULB, CHIPS, CUP, DECK, DIAMOND, FAN, GLASSES, JAM, KEYBOARD, MATCH, MOUSE, NAIL, NUT, PALM, RULER, SPADE, SPEAKER, SQUASH, TEMPLE, TRUNK, WAVE.

After revision of the tasks with 25 words (i.e. the determining the length a child would need to complete the task), it became clear that more items had to be cut. The item set was further reduced to 18 images based either on a low dominance-score (BAT) or high ERR in dom_neu (MOUSE, RULER) or high ERR in sub_bias (PALM), or overall high ERR in AmbWord. GLASSES was excluded as one could put either glasses in the dishwasher. The following item set was used in a pilot study with N = 8 children (Age = 12.47 ± 3.92, 4 males and 4 females):

BALL, BANK, ~~BAT~~, BOW, BULB, CHIPS, CUP, DECK, DIAMOND, FAN, ~~GLASSES~~, JAM, KEYBOARD, ~~MATCH~~, ~~MOUSE~~, NAIL, ~~NUT~~, ~~PALM~~, ~~RULER~~, SPADE, SPEAKER, SQUASH, TEMPLE, TRUNK, WAVE.

However, after another item-analysis with the children data, it turned out the selected items were not ideal CHIPS was therefore replaced by MATCH.

The final list of ambiguous words used in Study 2 and 3 was:

BALL, BANK, BOW, BULB, CUP, DECK, DIAMOND, FAN, JAM, KEYBOARD, MATCH, NAIL, SPADE, SPEAKER, SQUASH, TEMPLE, TRUNK, WAVE

See Figure B.3 for a depiction of the item selection process.

The final AMBWORD task used in the developmental studies consisted of 1 block with 54 trials lasting between 45 seconds (fastest adults) and 6 minutes (slowest child). The final AMBSENT task consisted of 144 trials (18 words x 8 conditions) in two blocks. Each block lasted between 60 seconds (fastest adult) and 8 minutes (slowest child).

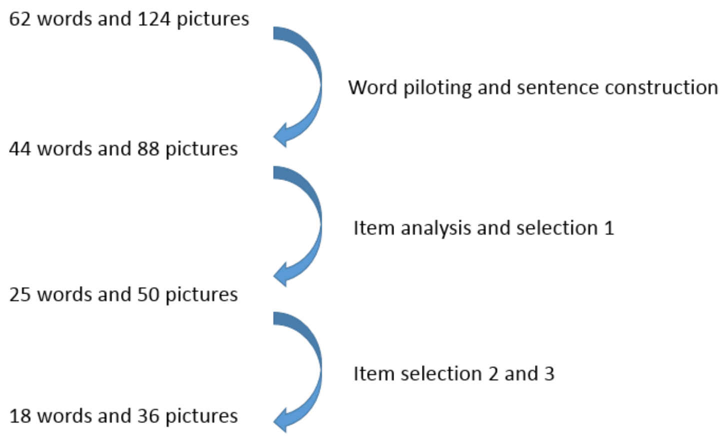



*Figure B.3.* Steps in the item selection process. From originally 62 ambiguous words 18 remained for usage in the study.

## B.2. Pilot Study: Sentence Ordering (Pilot-SENTORD)

### B.2.1. Stimuli and Procedure

For a description of the stimuli and procedure, please see Section 6.5.4.

### B.2.2. Results

The RT between the coherence ($M$ = 15.6 seconds) and temporal condition ($M$ = 16.1 seconds) did not differ ($p > 0.3$). However, accuracy was higher for temporally cued sentences (86.0%) than those from the coherence (73.4%) condition ($p = .045$). Readability Ease of each story did not correlate with the participants' average RT ($p = .441$) nor accuracy ($p = .258$) in that story. SENTORD was not altered for the main study.

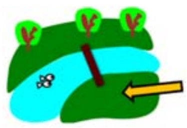
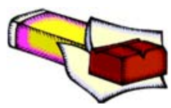
Overall, the pilot studies of AMBWORD, AMBSENT and SENTORD demonstrated that the selected tasks are valid tasks for measuring the intended constructs.

# Appendix C Stimulus Sets

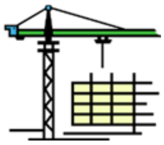
## C.1. AMBWORD & AMBSENT– Piloted Stimulus Set

Table C.2

*Piloted word-picture combinations for AMBWORD and AMBSENT together with the percentage of agreement in the pilot study WORDASSO and name agreement of the pictures in the pilot study PICNAME*

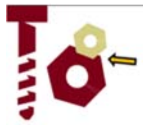
| | Dominant meaning | | | | Subordinate Meaning | | | |
|---|---|---|---|---|---|---|---|---|
| Word | Meaning / agreement in pilot | Picture | Names correctly in pilot / action taken | Accepted terms in pilot | Mean ing | Picture | Names correctly in pilot / action taken | Accepted terms in pilot |
| 1 BALL | round toy 100% |  | 100% | ball, beach ball | dance 0% |  | 94% | Ball (2%), dance/nightcl ub/concert/pa rty (92%) |
| 2 BANK | money institute 98% |  | 91% | bank | river 0% |  | .. | Bank (8%), grass/river/br idge/island/la nd (92%) |
| 3 BAR | drinking venue 82% |   | 62% will remove clover<br>changed | Bar (47%), pub (15%), ireland, st.patricks day... | chocolate 6% |  | 91% | chocolate, bar |
| 4 BAT | game stick 52% |  | 98% | Bat (98%) | animal 38% |  | 98% | bat |
| 6 BOW | arrow 32% |  | 70% | Bow (70%) | tie/ ribbon 48% |  | 96% | bow, ribbon, bow tie |

| | Dominant meaning | | | | Subordinate Meaning | | | |
|---|---|---|---|---|---|---|---|---|
| Word | Meaning / agreement in pilot | Picture | Names correctly in pilot / action taken | Accepted terms in pilot | Meaning | Picture | Names correctly in pilot / action taken | Accepted terms in pilot |
| 7 BULB | light 92% |  | 100% | light bulb, bulb | flower 6% |  | 89% | Bulb (32%), onion (4%), roots/seeds (53%) |
| 8 CHEST | body 66% |  | 94% | Chest (66%), pecs/muscles (28%) | furniture / box 26% 14% 12% |   | ? 79% | Chest (8%), drawer/cupboard (92%) chest (72%), trunk (8%) |
| 9 CHIPS | potato 96% |  | 100% | Chips (36%), fries (64%) | gamble 2% |  | 89% | chips (66%), token/ poker (23%) |
| 10 CLUB | night club 68% |  | 92% | Ball (2%), dance/nightclub/concert/party (92%) | golf/bat 8% |  | 79% | (golf) club (72%), golf stick (8%) |
| 11 COACH | bus 80% |  | 98% | coach (11%), bus (87%) | sport 14% |  | 79% | Coach (66%), trainer/teacher/refferee (13%) |
| 12 COLD | temp 82% |  | 89% | Cold (79%), freezing (9%) | sick 18% |  | 98% | cold (51%), ill/ sick (47%) |

| Word | Dominant meaning | | | | Subordinate Meaning | | | |
|---|---|---|---|---|---|---|---|---|
| | Meaning / agreement in pilot | Picture | Names correctly in pilot / action taken | Accepted terms in pilot | Meaning | Picture | Names correctly in pilot / action taken | Accepted terms in pilot |
| 13 CRANE | machine 64% |  | 89% | crane (62%), construction (26%) | bird 22% |  | 100% | Crane (13%), flamingo/stalk/ duck/stork/bird/swan/herron (87%) |
| 15 CUP | drink 98% |  | 100% | cup (2%), tea / coffee (98%) | sports 0% |  | 100% | Cup (8%), trophy (91%) |
| 16 DATE | time 54% |  | 75% | date (58%), calender (17%) | going out 34% |  | 87% | Date (87%) |
| 17 DECK | floor 62% |  | Arrow was missing | Deck (8%), sunbathing… | cards 30% |  | 99% | Deck (8%), cards (91%) |
| 18 DIAMOND | ring 98% |  | 98% | diamond (94%), gem, juwel (4%) | cards 0% |  | 96% | Diamond (96%) |
| 19 FAN | cooling 88% |  | 100% | fan | sport 2% | <br> | Changed picture | Fans (13%), cheering/celebration (42%), crowd (23%) |

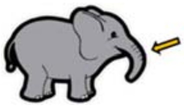
| Word | Dominant meaning | | | | Subordinate Meaning | | | |
|---|---|---|---|---|---|---|---|---|
| | Meaning / agreement in pilot | Picture | Names correctly in pilot / action taken | Accepted terms in pilot | Meaning | Picture | Names correctly in pilot / action taken | Accepted terms in pilot |
| 20 FILE | document 82% |  | 100% | file (43%), document (15%), folder/paper (42%) | nail 8% |  | 70% | File (66%), nail tool (4%) |
| 22 FOOT | body 88% |  | 100% | Foot (55%), leg (45%) | measure 0% |  | | Foot (2%), lenght/width (19%), ruler/measure (79%) |
| 23 GLASSES | eyes 92% |  | 98% | Glasses (96%), spectacles (2%) | drink 8% |  | 98% | Glasses (96%), flutes (2%) |
| 24 HORN | sound-maker 84% (car 62%, instrument 10%, sound 12%) |  | 87% | Horn (83%), honk (4%) | animal 12% |   | 96% Changed picture | Horn (96%) |
| 26 JAM | toast 98% |  | 100% | Jam (83%), jar (17%) | traffic 0% |  | | Traffic Jam/congestion/grdilock (21%), traffic/cars (49%) |
| 27 KEYBOARD | computer 82% |  | 98% | keyboard | music 12% |  | 100% | Keyboard (83%), (electric) piano (15%) |

| | Dominant meaning | | | | Subordinate Meaning | | | |
|---|---|---|---|---|---|---|---|---|
| Word | Meaning / agreement in pilot | Picture | Names correctly in pilot / action taken | Accepted terms in pilot | Meaning | Picture | Names correctly in pilot / action taken | Accepted terms in pilot |
| 28 KEYS | lock 92% |  | 100% | keys | keyboard 0% |  | 98% | Keys (57%), piano/keyboard (42%) |
| 29 KID | child 72% |   | plane will be remoed<br>Changed picture | Kid (2%), boy/ child (17%), fly/plane (42%) | animal 6% |  | 75% | Kid (9%), goat/lamb/calf (66%) |
| 31 MATCH | fire 44% |  | 100% | Match, -es, match sticks | game 34% |  | | Match (4%), game (4%), tennis/badminton/squashv (93%) |
| 32 MOLE | animal 78% |  | 70% | Mole (70%), beaver/badger/mouse.. (30%) | skin 22% |  | 100% | Mole (47%), beauty spot, freckle (53%) |
| 33 MOUSE | animal 64% |  | 100% | Mouse (91%), rat (9%) | computer 28% |  | 100% | mouse |
| 34 NAIL | finger 78% |  | 98% | Nail (81%), thumb (17%) | hammer 22% |  | 92% | Nail (66%), screw/pin (26%) |

| Word | Dominant meaning: Meaning / agreement in pilot | Dominant meaning: Picture | Dominant meaning: Names correctly in pilot / action taken | Dominant meaning: Accepted terms in pilot | Subordinate Meaning: Meaning | Subordinate Meaning: Picture | Subordinate Meaning: Names correctly in pilot / action taken | Subordinate Meaning: Accepted terms in pilot |
|---|---|---|---|---|---|---|---|---|
| 36 NUT | food 88% |  | 96% | Nut (19%), acorn (77%) | tool 4% | <br> | Changed picture | Nut (25%), bolt/screw (64%) |
| 38 ORGANS | body 86% |  | 77% | Organ (64%), digestive system/intestine (13%) | music 12% |  | 85% | Organ (62%), piano (23%) |
| 40 PALM | hand 70% |  | 96% | Palm (15%), hand (81%) | tree 26% |  | 92% | Palm (68%), tree (25%) |
| 42 PITCHER | drink 56% |  | 94% | Pitcher (0%), jug (94%) | game 16% |  | | Pitcher (15%), baseball/bowler/player/cricketer (85%) |
| 43 PLANT | green 98% |  | 98% | plant | nuclear 0% |  | 43% | (…) Plant (26%), nuclear/radiation (17%), factory/smoke/steam/pollution... |
| 45 PUNCH | hit 68% |  | 98% | Punch (85%), fight/boxing (13%) | paper 2%<br>Drink 18% | <br> | 96%<br>Changed picture/meaning | (hole) punch(-er) |

| | Dominant meaning | | | | Subordinate Meaning | | | |
|---|---|---|---|---|---|---|---|---|
| Word | Meaning / agreement in pilot | Picture | Names correctly in pilot / action taken | Accepted terms in pilot | Meaning | Picture | Names correctly in pilot / action taken | Accepted terms in pilot |
| 46 PUPILS | student 52% |  | 64% | Pupil (25%), student (40%) | eye 44% |  | | Pupil (89%), eye/iris (11%) |
| 48 RULER | measure 96% |  | 100% | ruler | king 2% |  | 100% | king |
| 49 SEAL | animal 80% |  | 98% | seal | letter 0% |  | 57% | Seal (23%), stamp (34%) |
| 50 SHAKE | drink 48% |  | 62% | (milk) shake (62%), drink/sundae/ice cream/desert (38%) | hand 14% |  | 85% | (hand) shake (83%), greeting (2%) |
| 52 SPADE | garden 88% |  | 98% | Spade (83%), shovel (15%) | cards 12% |  | 83% | Spade (83%) |
| 53 SPEAKER | loud-speaker 80% |   | 90% Changed picture | Speaker (60%), siren/megaphone/tanoid (30%) | talker 8% |  | 96% | Speaker/speech (70%), presenter/dictator/leader (26%) |

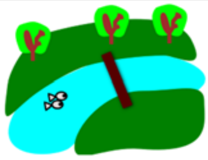
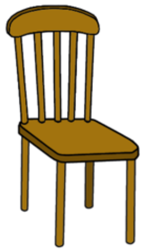
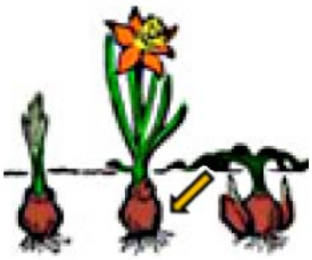
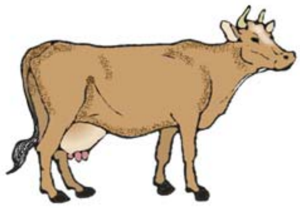
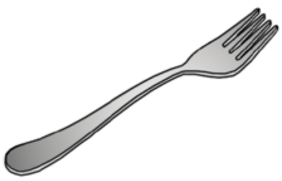
| | | | | Dominant meaning | | | | | Subordinate Meaning | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Word | | Meaning / agreement in pilot | | Picture | Names correctly in pilot / action taken | Accepted terms in pilot | Meaning | | Picture | Names correctly in pilot / action taken | Accepted terms in pilot |
| 54 | SQASH | drink | 46% |  | 89% | Squash (53%), juice (36%) | veggie | 0% |  | 68% | Squash (60%), pumpkin/marrow (8%) |
| 54 | SQUASH | sport | 40% |  | 49% | Squash (21%), racket (28%), tennis/badminton (43%) | veggie | 0% |  | 68% | Squash (60%), pumpkin/marrow (8%) |
| 55 | STRAW | drink | 72% |  | 89% | Straw (89%) | hay | 20% | <br> | 74%<br>Changed picture | Straw (6%), hay (68%), spaghetti |
| 56 | TEMPLE | religious | 72% |  | 62% | Temple (45%), museum/church (17%) | head | 24% | <br> | romove spot<br>Changed picture | Temple (9%), mole/beatyspot/pimple, hairline (91%) |
| 57 | TICK | correct | 50% |  | 92% | Tick (92%) | bug | 4% |  | 100% | Tick (6%), bug/spider/insect (94%) |
| 58 | TOAST | bread | 94% |  | 100% | Toast (62%), toaster (38%) | drink | 2% |  | 28% | Toast (6%), cheers (23%), Champaign glasses/flutes (72%) |

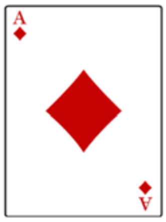
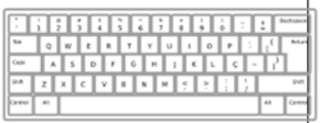
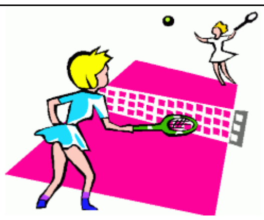
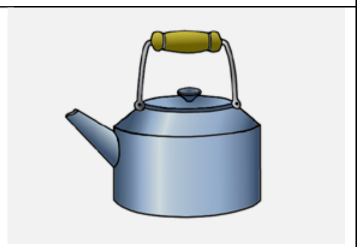
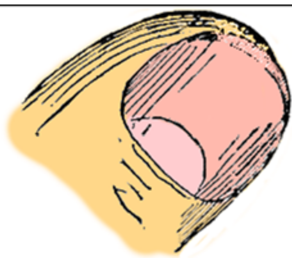
| | Dominant meaning | | | | Subordinate Meaning | | | |
|---|---|---|---|---|---|---|---|---|
| Word | Meaning / agreement in pilot | Picture | Names correctly in pilot / action taken | Accepted terms in pilot | Meaning | Picture | Names correctly in pilot / action taken | Accepted terms in pilot |
| 60 TRUNK | elephant 30% |  | 94% | Trunk (94%), elefant (6%) | tree 10% |   | 76%<br>Changed picture | Trunk (36%), tree (40%), monster |
| 62 WAVE | water 64% |  | 100% | Wave (81%), sea (19%) | bye 18% |   | add arrow<br>Changed picture | Wave (8%), tourist/photographer/explorer/bird watcher (92%) |

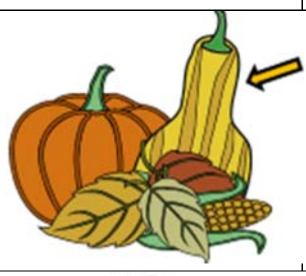
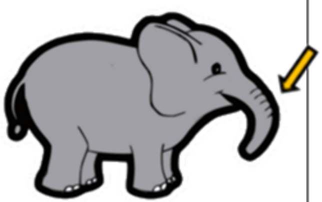
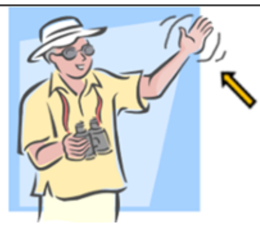
## C.2. AMBWORD – Final Stimulus Set

Table C.3

*Final stimulus set for the Task AMBWORD*

| Ambiguous Word | Picture for dominant meaning | Picture for subordinate meaning | Unrelated picture |
|---|---|---|---|
| BALL |  |  |  |
| BANK |  |  |  |
| BOW |  |  |  |
| BULB |  |  |  |
| CUP |  |  |  |
| DECK |  |  |  |

| Ambiguous Word | Picture for dominant meaning | Picture for subordinate meaning | Unrelated picture |
|---|---|---|---|
| DIAMOND |  |  |  |
| FAN |  |  |  |
| JAM |  |  |  |
| KEYBOARD |  |  |  |
| MATCH |  |  |  |
| NAIL |  |  |  |

| Ambiguous Word | Picture for dominant meaning | Picture for subordinate meaning | Unrelated picture |
| --- | --- | --- | --- |
| SPADE |  |  |  |
| SPEAKER |  |  |  |
| SQUASH |  |  |  |
| TEMPLE |  |  |  |
| TRUNK |  |  |  |
| WAVE |  |  |  |

## C.3. Lexical measures for the words selected for AMBWORD and AMBSENT

Table C.4

*Lexical measures for the selected words as provided by the program N-watch (Davis, 2005)*

| **WORD** | **CELEX** | **BNC_FRQ** | **EST_FRQ** | **FAM** | **AOA** | **AOA2** | **IMG** | **IMG2** |
|---|---|---|---|---|---|---|---|---|
| | | British National Corpus | subjective frequency | subjective familiarity | age of acquisition 1 | age of acquisition 2 | imageability 1 | imageability 2 |
| | frequency per million | | 100: little 700: highly | | 100: early 700: late | | 100: difficult 700: easy | |
| BALL | 92.96 | 73.79 | 530 | 575 | 150 | | 622 | |
| BANK | 133.02 | 189.52 | 480 | 573 | | | 560 | |
| BOW | 20.78 | 15.47 | 359 | 489 | 271 | | 546 | |
| BULB | 6.48 | 4.23 | 417 | 510 | 293 | | 611 | |
| CUP | 60.84 | 123.72 | 633 | 595 | | | 558 | |
| DECK | 19.16 | 15.09 | 363 | 507 | 347 | | 539 | |
| DIAMOND | 7.82 | 11.37 | | 512 | 339 | | 623 | |
| FAN | 11.56 | 18.09 | 455 | 520 | | | 582 | |
| JAM | 13.24 | 9.82 | 413 | 529 | | | 569 | |
| KEYBOARD | 2.63 | 9.94 | | | | | | |
| MATCH | 56.98 | 100.72 | 467 | 558 | | 426 | 490 | 403 |
| NAIL | 12.01 | 7.2 | 469 | 563 | 272 | | 588 | |
| SPADE | 2.85 | 2.94 | 280 | 513 | | | 578 | |
| SPEAKER | 17.21 | 92.49 | | 554 | | 420 | 549 | |
| SQUASH | 8.77 | 6.03 | 333 | 533 | 283 | | 483 | |
| TEMPLE | 23.24 | 22.92 | | 450 | | | 547 | |
| TRUNK | 19.83 | 8.31 | 400 | 485 | 328 | | 529 | |
| WAVE | 45.36 | 37.98 | 450 | 551 | 260 | 213 | 594 | |

## C.4. AMBSENT – Final Stimulus Set

Table C.5

*Final stimulus set for the task AMBSENT*

| | | CONTEXTUAL FACILITATION condition | | | CONTEXTUAL SUPPRESSION condition | | |
|---|---|---|---|---|---|---|---|
| | Word | Sentence type | Sentence | Picture type | Sentence type | Sentence | Picture type |
| 1 | BALL | Neutral (dominant) | She wanted a BALL. | TOY | Ambiguous (dominant) | She played with a BALL. | DANCE |
| | | Neutral (subordinate) | She wanted a BALL. | DANCE | Ambiguous (subordinate) | She met him at a BALL. | TOY |
| | | Biased (dominant) | She played with a BALL. | TOY | Unambiguous (dominant) | She played with a DOLL. | DANCE |
| | | Biased (subordinate) | She met him at a BALL. | DANCE | Unambiguous (subordinate) | She met him on a CONFERENCE. | TOY |
| 2 | BANK | Neutral (dominant) | He ran from the BANK. | MONEY | Ambiguous (dominant) | He stole from the BANK. | RIVER |
| | | Neutral (subordinate) | He ran from the BANK. | RIVER | Ambiguous (subordinate) | He fished from the BANK. | MONEY |
| | | Biased (dominant) | He stole from the BANK. | MONEY | Unambiguous (dominant) | He stole from the SHOP. | RIVER |
| | | Biased (subordinate) | He fished from the BANK. | RIVER | Unambiguous (subordinate) | He fished from the STREAM. | MONEY |
| 6 | BOW | Neutral (dominant) | She bought the BOW. | RIBBON | Ambiguous (dominant) | She wore the BOW. | ARROW |
| | | Neutral (subordinate) | She bought the BOW. | ARROW | Ambiguous (subordinate) | She strung the BOW. | RIBBON |
| | | Biased (dominant) | She wore the BOW. | RIBBON | Unambiguous (dominant) | She wore the TIE. | ARROW |
| | | Biased (subordinate) | She strung the BOW. | ARROW | Unambiguous (subordinate) | She strung the GUITAR. | RIBBON |
| 7 | BULB | Neutral (dominant) | He bought the BULB. | LIGHT | Ambiguous (dominant) | He changed the BULB. | PLANT |
| | | Neutral (subordinate) | He bought the BULB. | PLANT | Ambiguous (subordinate) | He planted the BULB. | LIGHT |
| | | Biased (dominant) | He changed the BULB. | LIGHT | Unambiguous (dominant) | He changed the LIGHT. | PLANT |
| | | Biased (subordinate) | He planted the BULB. | PLANT | Unambiguous (subordinate) | He planted the SEED. | LIGHT |
| 15 | CUP | Neutral (dominant) | She carried the CUP. | TEA | Ambiguous (dominant) | She won the tea CUP. | TROPHY |
| | | Neutral (subordinate) | She carried the CUP. | TROPHY | Ambiguous (subordinate) | She won the world CUP. | TEA |
| | | Biased (dominant) | She won the tea CUP. | TEA | Unambiguous (dominant) | She won the tea POT. | TROPHY |
| | | Biased (subordinate) | She won the world CUP. | TROPHY | Unambiguous (subordinate) | She won the world CHAMPIONSHIP. | TEA |

| | CONTEXTUAL FACILITATION condition | | | CONTEXTUAL SUPPRESSION condition | | |
|---|---|---|---|---|---|---|
| Word | Sentence type | Sentence | Picture type | Sentence type | Sentence | Picture type |
| 17 DECK | Neutral (dominant) | He looked at the DECK. | FLOOR | Ambiguous (dominant) | He swept the DECK. | FLOOR |
| | Neutral (subordinate) | He looked at the DECK. | CARDS | Ambiguous (subordinate) | He shuffled the DECK. | CARDS |
| | Biased (dominant) | He swept the DECK. | FLOOR | Unambiguous (dominant) | He shuffled the CARDS. | FLOOR |
| | Biased (subordinate) | He shuffled the DECK. | CARDS | Unambiguous (subordinate) | He swept the PATIO. | CARDS |
| 18 DIAMOND | Neutral (dominant) | He saw the DIAMOND. | JEWEL | Ambiguous (dominant) | He polished the DIAMOND. | CARD |
| | Neutral (subordinate) | He saw the DIAMOND. | CARD | Ambiguous (subordinate) | He played the DIAMOND. | JEWEL |
| | Biased (dominant) | He polished the DIAMOND. | JEWEL | Unambiguous (dominant) | He polished the GOLD. | CARD |
| | Biased (subordinate) | He played the DIAMOND. | CARD | Unambiguous (subordinate) | He played the ACE. | JEWEL |
| 19 FAN | Neutral (dominant) | She saw the FAN. | AIR | Ambiguous (dominant) | The FAN created a breeze. | SPORT |
| | Neutral (subordinate) | She saw the FAN. | SPORT | Ambiguous (subordinate) | The FAN created a chant. | AIR |
| | Biased (dominant) | The FAN created a breeze. | AIR | Unambiguous (dominant) | The AIR-CON created a breeze. | SPORT |
| | Biased (subordinate) | The FAN created a chant. | SPORT | Unambiguous (subordinate) | The SINGER created a chant. | AIR |
| 26 JAM | Neutral (dominant) | The JAM was still there. | TOAST | Ambiguous (dominant) | The strawberry JAM was still there. | TRAFFI C |
| | Neutral (subordinate) | The JAM was still there. | TRAFFI C | Ambiguous (subordinate) | The traffic JAM was still there. | TOAST |
| | Biased (dominant) | The strawberry JAM was still there. | TOAST | Unambiguous (dominant) | The strawberry CAKE was still there. | TRAFFI C |
| | Biased (subordinate) | The traffic JAM was still there. | TRAFFI C | Unambiguous (subordinate) | The traffic WARDEN was still there. | TOAST |
| 27 KEYBOARD | Neutral (dominant) | She put the KEYBOARD on the table. | COMPU TER | Ambiguous (dominant) | She wrote a letter on the KEYBOARD. | MUSIC |
| | Neutral (subordinate) | She put the KEYBOARD on the table. | MUSIC | Ambiguous (subordinate) | She played a song on the KEYBOARD. | COMPU TER |
| | Biased (dominant) | She wrote a letter on the KEYBOARD. | COMPU TER | Unambiguous (dominant) | She wrote a letter on the COMPUTER. | MUSIC |
| | Biased (subordinate) | She played a song on the KEYBOARD. | MUSIC | Unambiguous (subordinate) | She played a song on the PIANO. | COMPU TER |

| | | CONTEXTUAL FACILITATION condition | | | CONTEXTUAL SUPPRESSION condition | | |
|---|---|---|---|---|---|---|---|
| Word | | Sentence type | Sentence | Picture type | Sentence type | Sentence | Picture type |
| 31 | MATCH | Neutral (dominant) | This is a MATCH. | FIRE | Ambiguous (dominant) | She lit the MATCH. | GAME |
| | | Neutral (subordinate) | This is a MATCH. | GAME | Ambiguous (subordinate) | She won the MATCH. | FIRE |
| | | Biased (dominant) | She lit the MATCH. | FIRE | Unambiguous (dominant) | She lit the FIRE. | GAME |
| | | Biased (subordinate) | She won the MATCH. | GAME | Unambiguous (subordinate) | She won the GAME. | FIRE |
| 34 | NAIL | Neutral (dominant) | This is a NAIL. | FINGER | Ambiguous (dominant) | She used a NAIL file. | HAMM ER |
| | | Neutral (subordinate) | This is a NAIL. | HAMM ER | Ambiguous (subordinate) | She used a NAIL gun. | FINGER |
| | | Biased (dominant) | She used a NAIL file. | FINGER | Unambiguous (dominant) | She used a DATA file. | HAMM ER |
| | | Biased (subordinate) | She used a NAIL gun. | HAMM ER | Unambiguous (subordinate) | She used a GLUE gun. | FINGER |
| 52 | SPADE | Neutral (dominant) | He picked up the SPADE. | TOOL | Ambiguous (dominant) | He dug with the SPADE. | CARDS |
| | | Neutral (subordinate) | He picked up the SPADE. | CARDS | Ambiguous (subordinate) | He played the SPADE. | TOOL |
| | | Biased (dominant) | He dug with the SPADE. | TOOL | Unambiguous (dominant) | He dug with the SHOVEL. | CARDS |
| | | Biased (subordinate) | He played the SPADE. | CARDS | Unambiguous (subordinate) | He played the CARD. | TOOL |
| 53 | SPEAKER | Neutral (dominant) | The SPEAKER was loud. | LOUDS PEAKE R | Ambiguous (dominant) | The SPEAKER was broken. | PRESE NTER |
| | | Neutral (subordinate) | The SPEAKER was loud. | PRESEN TER | Ambiguous (subordinate) | The SPEAKER was ill. | LOUDS PEAKE R |
| | | Biased (dominant) | The SPEAKER was broken. | LOUDS PEAKE R | Unambiguous (dominant) | The GLASS was broken. | PRESE NTER |
| | | Biased (subordinate) | The SPEAKER was ill. | PRESEN TER | Unambiguous (subordinate) | The PRESENTER was ill. | LOUDS PEAKE R |
| 54 | SQASH | Neutral (dominant) | He likes SQUASH. | DRINK | Ambiguous (dominant) | He drank the SQUASH. | VEGET ABLE |
| | | Neutral (subordinate) | He likes SQUASH. | VEGET ABLE | Ambiguous (subordinate) | He baked the SQUASH. | DRINK |
| | | Biased (dominant) | He drank the SQUASH. | DRINK | Unambiguous (dominant) | He drank the JUICE. | VEGET ABLE |
| | | Biased (subordinate) | He baked the SQUASH. | VEGET ABLE | Unambiguous (subordinate) | He baked the PUMPKIN | DRINK |

| | CONTEXTUAL FACILITATION condition | | | CONTEXTUAL SUPPRESSION condition | | |
|---|---|---|---|---|---|---|
| Word | Sentence type | Sentence | Picture type | Sentence type | Sentence | Picture type |
| 56 TEMPLE | Neutral (dominant) | She pointed at the TEMPLE. | BUILDING | Ambiguous (dominant) | She went into the TEMPLE. | HEAD |
| | Neutral (subordinate) | She pointed at the TEMPLE. | HEAD | Ambiguous (subordinate) | She had pain in her TEMPLE. | BUILDING |
| | Biased (dominant) | She went into the TEMPLE. | BUILDING | Unambiguous (dominant) | She went into the BUILDING. | HEAD |
| | Biased (subordinate) | She had pain in her TEMPLE. | HEAD | Unambiguous (subordinate) | She had pain in her ARM. | BUILDING |
| 60 TRUNK | Neutral (dominant) | She saw the TRUNK. | ELEPHANT | Ambiguous (dominant) | The elephant has a TRUNK. | TREE |
| | Neutral (subordinate) | She saw the TRUNK. | TREE | Ambiguous (subordinate) | The tree has a TRUNK. | ELEPHANT |
| | Biased (dominant) | The elephant has a TRUNK. | ELEPHANT | Unambiguous (dominant) | The elephant has a TAIL. | TREE |
| | Biased (subordinate) | The tree has a TRUNK. | TREE | Unambiguous (subordinate) | The tree has ROOTS. | ELEPHANT |
| 62 WAVE | Neutral (dominant) | She saw the WAVE. | WATER | Ambiguous (dominant) | She surfed the WAVE. | GOODBYE |
| | Neutral (subordinate) | She saw the WAVE. | GOODBYE | Ambiguous (subordinate) | She returned the WAVE. | WATER |
| | Biased (dominant) | She surfed the WAVE. | WATER | Unambiguous (dominant) | She surfed the OCEAN. | GOODBYE |
| | Biased (subordinate) | She returned the WAVE. | GOODBYE | Unambiguous (subordinate) | She returned the KISS. | WATER |

## C.5. SENTORD – Stimulus Set

SET 1 – Coherence

1 **A man building his own home**

- [ ] At a local auction John bought a very large
- [ ] Builders arrived to dig the foundations
- [ ] The builders then set about building the walls
- [ ] It was not long before John could put the
- [ ] John's wife ordered a new suite of furniture

1 **A child starting school for the first time**

- [ ] Amy was getting ready for her first day at
- [ ] Amy started to cry when her mother left her
- [ ] The teacher was kind to Amy and gave her
- [ ] Amy soon began to make friends with all the
- [ ] When Amy was older she had to start at a

1 **Children play hide and seek with their friends**

- [ ] Max and Lisa played hide and seek in the
- [ ] Max was counting while the others were
- [ ] Everyone had found a clever hiding spot.
- [ ] But it was not long before Max had found
- [ ] The only one missing was Lisa who was hiding

1 **A boy celebrates his Birthday with his family**

- [ ] Adam woke up in the morning of his 10th
- [ ] Adam quickly got dressed and ran downstairs
- [ ] Adam saw his parents had prepared a big
- [ ] They sat down and everyone was chatting
- [ ] For dessert the whole family ate Adam's big,

SET 2 – Coherence

2 **Making friends with a horse**

- [ ] Charlotte found a wild horse whilst living
- [ ] The horse would gallop away every time
- [ ] The horse slowly began to stay still when
- [ ] The horse then let Charlotte touch him for a
- [ ] It was not long before Charlotte was able to

2 **A man goes to the supermarket**

- [ ] Bob left the house after putting on his jacket
- [ ] At the shop Bob took a basket and started
- [ ] Bob crossed off the items he had already
- [ ] Only when he got to the till did Bob realise
- [ ] Bob quickly grabbed some milk and went to

2 **A girl is getting ready for bed**

- [ ] Sally's Mum told Sally to get ready for bed.
- [ ] After brushing her teeth Sally went to her
- [ ] Sally's Mum read her favourite bedtime story
- [ ] The Mum and Sally wishes each other good
- [ ] It was not long before Sally had fallen asleep.

2 **A girl enjoys reading a book**

- [ ] On Saturday Judy bought a new book in the
- [ ] Judy was looking forward to getting home so
- [ ] Judy sat on the sofa and read until it was very
- [ ] The next day Judy read until she had finally
- [ ] Judy liked it so much that she recommended

SET 1 - Temporal

1 **Making a garden look nice**

- [ ] Late one summer morning Tina set about
- [ ] By lunch time all the weeds and rubbish had
- [ ] By mid-afternoon Tina had made the lawn
- [ ] Later that afternoon Tina went to the shops
- [ ] By evening Tina had made her garden look

1 **Preparing for a dinner or preparing and cooking a dinner**

- [ ] Mrs Smith set out at lunch time to buy all the
- [ ] That afternoon Mrs Smith got home from the
- [ ] Towards dinner time, Mrs Smith began
- [ ] By early evening the dinner was almost
- [ ] That evening Mr Smith returned home and

1 **A woman's work day**

- [ ] When Mrs Bush left the house in the morning
- [ ] Mrs Bush went to work and had two
- [ ] After lunch Mrs Bush wrote a lot of emails
- [ ] In the afternoon Mrs Bush's boss told her she
- [ ] Therefore, she was already home when Mr

1 **A couple's holiday**

- [ ] Kelly and Matt arrived at their holiday
- [ ] They decided to go to the beach on the first
- [ ] On Tuesday, they went into the city for
- [ ] The next few days until the weekend they
- [ ] Kelly and Matt were very sad when they had

SET 2 - Temporal

2 **A fireman's shift**

- [ ] The fireman left his home in the late afternoon
- [ ] The fireman ate his dinner with the other men,
- [ ] Soon after dinner the siren sounded because of
- [ ] All night they fought to put out the fire which
- [ ] In the early hours of the morning the firemen

2 **A family trip to the zoo**

- [ ] Mary and her family decided to go to the zoo on
- [ ] In the morning, they all had a big breakfast at
- [ ] Around midday, the family arrived in the zoo
- [ ] However, the kids were already hungry again in
- [ ] The family ate some sandwiches and came

2 **The story of a girl who became a hockey player**

- [ ] When Mary was born she was a chubby little
- [ ] By the time Mary was four, she had grown up
- [ ] A few years after starting primary school Mary
- [ ] As a teenager, Mary was a very good player and
- [ ] Some years later, she was very happy to be

2 **Cooking a soup**

| | |
|---|---|
| | First, he chopped up some onions, potatoes, |
| | As a second step, he added frozen peas and |
| | When the vegetables were soft, he added a can |
| | Just before finishing, he decided to blend |
| | At the end, he added salt and pepper, stirred in |

C.6. SENTCOMP – Stimulus Set

**PRACTICE:** He cleaned up the mess with a brush and…

I was given a pen and…

The sea tastes of salt and…

Hens lay eggs and…

The woman took the cup and…

You can get burnt by the sun and…

You can feed a child bread and…

Little boys grow up to be men and…

In the sea there are fish and…

In a cave lived a bat and…

You can go hunting with a knife and…

The old shoemaker mended the shoes and…

The fireman carried the bucket and…

A vet cares for cats and…

The night was black and…

(Were you thinking of a knight on a horse or a starry night?)

# Appendix D Measures and Tasks excluded after piloting

In the first pilot study piloting of CONTI and CONTMASK other measures were obtained which were later excluded from following investigations. These included questionnaires about participants' mood (PANAS, Dino-VAS), a head circumference measure (HC), as well as a homograph reading task (HOMOREAD). These measures will be shortly described, results of the pilot studies presented and reasons for the exclusion of the tasks elaborated.

26 participants (8 males, 18 females) with a mean age of M = 27.4yrs (SD = 3.55) took part in the first pilot study. Of those 26 participants, 15 completed the whole pilot study (CONTI, CONTMASK, HC, AQ, Mood), 2 dropped out half way (only CONTMASK) and 9 completed only the questionnaires (HC, AQ, Mood). 13 were English native speakers who completed the reading task (HOMOREAD).

## D.1. Mood questionnaires (PANAS, Dino-VAS)

As briefly mentioned in chapter XXX mood has been found to influence local and global precedence (Basso, Schefft, Ris, & Dember, 1996; Baumann and Kuhl, 2005; Bianchi & Laurent, 2009, 2010; De Fockert & Cooper, 2014; Gasper, 2004; Gasper & Clore, 2002; Mottron, Dawson, Soulières, Hubert, & Burack, 2006). We explored in our pilot study whether any mood effects can be found regarding visual processing styles. For this reason participants were asked to complete two questionnaires: the PANAS and Dino-VAS. The Dino-VAS was a child friendly questionnaire created for this study. As it was meant to be used as a mood questionnaire in the main studies, its convergent validity, i.e. the correlation of Dino-VAS and PANAS was examined in the pilot study.

### D.1.1. Positive and Negative Affective Schedule (PANAS)

The PANAS (Watson, Clark, & Tellegen, 1988) comprises a positive and a negative mood scale, each consisting of 10 items that have to be rated on a scale from 1 (very slightly or not at all) to 5 (extremely). Two different instructions were used, one asking the participant to indicate how he *usually* feels on an average day (1st session), one asking about the *current* state (2nd, 3rd session). The positive and negative scores were averaged to a negative and positive mood score. For comparison with the Dino-

VAS, the negative score was subtracted from the positive score to receive one overall score [-5,+5] and converted (score / 5 * 3), so it would be equivalent to the Dino-VAS and have -3 as the minimum, 0 as neutral and +3 as the maximum score.

### D.1.2. Dinosaur Visual Analogue Scale (Dino-VAS)

The Dino-VAS uses pictures from the book "A Dinosaur shows emotions" ("Ein Dino zeigt Gefühle", Löffel & Manske, 1996) that have been selected in order to represent pairs of emotions, e.g. happy and sad. The participants were asked to indicate their emotions by crossing a continuous line between the two end points (Visual Analog Scale, VAS). As with the PANAS, there was a trait ("How do you *usually* feel on a normal day") and a state version ("How do you feel *right now*?"). Participants filled it in before and after the visual processing task. The scales had a minimum sore of -3, and maximum of +3. A score of 0 indicated neural mood (neither positive nor negative)

### D.1.3. Pilot Results

On average the participants scored $M = 0.97$ ($SD = .97$) on the trait version of the Dino-VAS and 1.12 ($SD = .53$) on the PANAS. The scores did not differ, $t(25) = -1.124$, $p = .272$. The convergent validity of the DINO-VAS was good ($r = .732$, $p < .001$).

### D.1.4. Reason for exclusion

Although the DINO-VAS was a reliable measure for trait and state emotions, the pilot data showed they were in no relation with the behavioural data or perceptual biases in CONTI and CONTMASK. It was therefore decided to exclude the mood questionnaires from further experiments.

## D.2. Head Circumference (HC)

In the scope of autism research, it has been proposed that there are subgroups of individuals with ASD who differ in the extent of CC. For example, White, O'Reilly, and Frith (2009) found that head size covaries with the ability to switch from local to global processing in ASD and O'Reilly, Thiebaut, and White (2013) demonstrated that a local processing bias is more pronounced in autistic individuals with macrocephaly ("bigger brains", $z > 1.88$). O'Reilly et al. (2013) also report that larger heads in ASD are associated with increased local bias.

It could be possible that the relationship between head size/brain volume and processing styles is not exclusive for participants with ASD, but that it also applies to TD who exhibit autistic traits. We therefore wanted to explore how head circumference was associated with autistic traits and with processing styles on the visual task in TD. Therefore, head circumference, height and gender were used to calculate a z-score based on norm data provided by Bushby, Cole, Matthews, and Goodship (1992).

### D.2.1. Pilot Results

The pilot-studies of CONTI and CONTMASK revealed no correlations of head circumference (HC) and the visual data. However, significant positive correlations were found between head circumference and autistic traits ($AQ_{Total}$ & HC: $r = .454$, $p = .020$, see Figure D.1). More precisely, the bigger the head of the participant, the higher the scores on the subscales lack of social skills ($AQ_{SOC}$ & HC: $r = .394$, $p = .046$), and attention to detail ($AQ_{ATD}$ & HC: $r = .555$, $p = .003$). When the AQ subscale scores were entered into a linear regression, attention to detail alone explained 32.7% of the variance in HC. After social skills were added into the model the total variance explained was 44.7%, $F(2,23) = 9.351$, $p = .001$. None of the other variables were reliable predictors for HC (all $p > .05$).

However, in a new sample of 20 participants (included in the experiment STIMMIX), the correlations were no longer significant ($n = 20$, $AQ_{Total}$ & HC: $r = -.279$, $p = .221$; $AQ_{ATD}$ & HC: $r = .020$, $p = .930$), also not when combining the samples ($n = 46$, $AQ_{Total}$ & HC: $r = .126$, $p = .403$) or adding the data from the remaining participants from Experiment 2 & 3 in Study 1 ($n = 59$, $AQ_{Total}$ & HC: $r = .050$, $p = .707$, see also Figure D.2).

### D.2.1. Reason for exclusion

It is likely that the positive correlations from the first pilot were due to sample effects, e.g. due do not being a representative sample (mainly social science and science PhD students). As the correlations were not confirmed by the data of the first study, it was decided not to explore this further in the developmental and clinical samples.

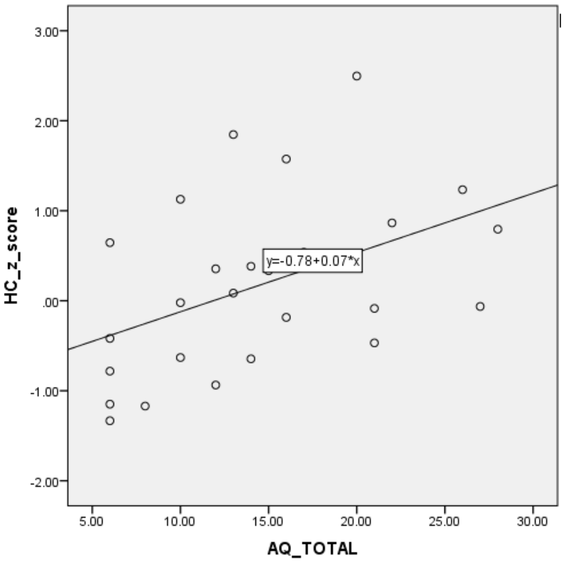



*Figure D.1.* Scatterplot showing the relationship between $HC_{z\text{-scores}}$ and $AQ_{Total}$ Scores in the pilot population of *n* = 26. $R^2$ linear = 0.206

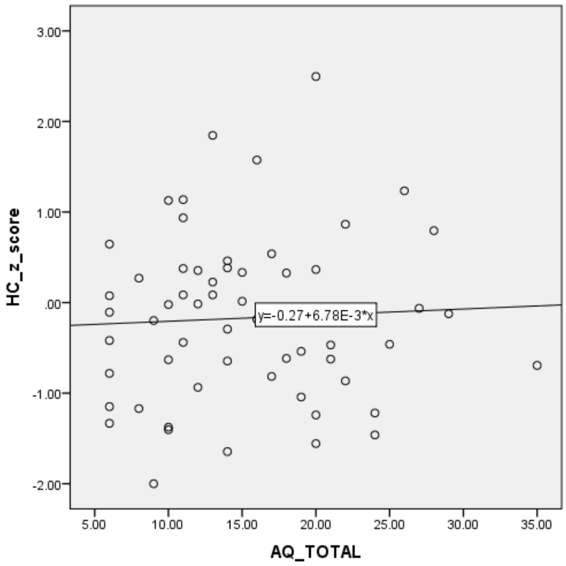



*Figure D.2.* Scatterplot showing the relationship between of $HC_{z\text{-scores}}$ and $AQ_{Total}$ Scores in the combined populations of the pilot and first study (Exp.1-3) of *n* = 59. $R^2$ linear = 0.002.

## D.3. Homograph Reading Task (HOMOREAD)

The homograph reading task (adapted from Frith & Snowling, 1983) was introduced as a measure to examine global processing in language, i.e. use of context information when reading sentences containing homographs (words with two possible pronunciations and therefore two separate meanings, e.g. lead). The task consisted of two parts. In the first part 30 sentences had to be read aloud. 20 of them each included one of 5 homographs and stemmed from Frith and Snowling’s (1983) original task, 10 were filler sentences that included homophones (e.g. tail and tale) in order to make the nature of the task less obvious. Participants were told before the start they may correct themselves if they realised they made a mistake. In the second part the homographs and homophones had to be read aloud (single words) and participants were asked to say all possible pronunciations if a word had more than one. This was done in order to check whether participants knew both possible pronunciations but still made errors in the sentence reading task.

For the analysis, sentences were counted in which the homograph was pronounced correctly. This was done separately for homographs appearing before or after the context information of a sentence, as well as for pronunciations with a higher and lower frequency.

### D.3.1. Pilot Results

In the pilot study, 13 English native speakers (7 females, 6 males, age M = 27.22, SD = 3.79) completed the homograph reading task. A 2x2 ANOVA explored the effects of frequency (rare vs frequent pronunciation) and context (before vs after homograph) on reading accuracy of the homographs.

The results indicated that participants made mistakes when reading sentences containing homographs, even though they were allowed to correct themselves and knew both possible pronunciations (as checked with the single word reading). On average, in 81.15% (approx.16/20, SD = 11.02%) of sentences the homographs were read correctly in the first attempt, in 90.38% (approx. 18/20, SD = 11.08%) when corrections were included. When analysing the accuracy (incl. correction) further, a 2x2 ANOVA with the factors frequency (more or less frequent pronunciation) and context (before or after the homograph) showed that context had a main effect on the accuracy, $F(1,12) = 8.157$, $p = .014$, $\eta 2 = .405$, with less errors when the context was present earlier in the sentence, i.e. before the homograph (4.7 out of 5 correct) than when it was presented afterwards (4.3 out of 5 words correct). Frequency as well as the interaction of frequency and context did not have an effect ($p > .05$).

Poor performance on the homograph reading task was not associated to any other assessed variables in the visual task or AQ or HC. Interestingly, not all TD participants used context information in order to find the right pronunciation for the homograph. While some participants noticed the homograph status of the words and read without any mistakes (or corrected themselves), others completed the task with errors without realising the nature of the task. Frith and Snowling's (1983) conclusion that TD use context information when reading homographs while individuals with ASD do not, is therefore not as universal . As Brock and Bzishvili (2013) showed in an eye-tracking study, homograph reading in TD depends on a number of factors, e.g. the eye-to-voice span and interference from previous trials. However, these factors are only applicable for the first attempt to pronounce the homograph of a sentence (without corrections). Participants in the pilot study were explicitly told that they can correct themselves if they made a mistake and all of them knew both possible pronunciations. Therefore, the error rate in these participants cannot be attributed to Brock's two factors, but rather to a lack of usage of context information.

### D.3.2. Reason for exclusion

The homograph reading task was later rejected due to the confounding general reading ability. Only skilled readers can read ahead or grasp the whole sentence at once and therefore use context that comes after the homograph. Alternatively, some participants could have first read the sentence quietly to the end and then repeated it out loud (with consideration of the context), whereas others read the sentences aloud word by word. The task is not (only) measuring the ability to "read for meaning" but also general reading proficiency. Unless an additional reading test was introduced, the confounding reading ability could not be controlled for. A different alternative would be to record the sentences with the correct and wrong pronunciations and play the recoded sentences to the participants who would be asked to decide whether the given sentence made sense or not.

Once the homograph reading task proved to be an unsatisfactory measure for local and global processing in language, it was replaced by the three tasks AMBWORD, AMBSENT, SENTORD and later SENTCOMP.

# Appendix E ASD Questionnaires: SCQ and CCC

## E.1. Social Communication Questionnaire (SCQ)

The Social Communication Questionnaire (SCQ, Rutter et al., 2003) was implemented as a confirmation of the ASD diagnosis and was given to parents/carers in the ASD group. In the TD group, most parents did not complete the questionnaire as it was only introduced at a later stage of the investigation during the recruitment and assessment of ASD participants.

The SCQ is a screening tool assessing children with a minimum mental age of 2 years for (severity of) ASD symptoms. Two parts are completed by a parent or other caregiver: 19 yes/no questions regarding the current state and 21 yes/no questions regarding the developmental history. The items match the questions asked during the ADI-R. A research-based cut-off score of 15 points or more indicates individuals that are likely to have ASD.

The validity was assessed in 4 studies that showed that SCQ and ADI-R have a high agreement regarding total scores and domains (Rutter et al., 2003). Internal Consistency (alpha) ranges in different age-groups between .84 and .93 and in different groups between .81 (Autism), .86 (ASD) and .92 (Nonspectrum).

## E.2. Communication Checklist (CCC, CCA)

The Communication Checklists CCC (Bishop, 2003) and CCA (Whitehouse & Bishop, 2009) served as another proxy measure for ASD Symptoms. It was completed for ASD children (CCC) and most ASD adults (CCA), but only for some TD participants.

### E.2.1. Children's Communication Checklist (CCC):

The Children's Communication Checklist (officially CCC-2, but labelled CCC in this investigation; Bishop, 2003) is a tool for assessing language abilities and impairments in children aged 4-16. It consists of 10 scales covering aspects of language structure, pragmatic communication and social relations and interests – aspects that are usually affected in ASD (see table below). Each scale has 7 items (5 covering difficulties, 2 covering strengths) that have to be rated by a parent or carer regarding frequency of occurrence (0: less than once a week or never, 1: at least once a week, but not every day; 2: once or twice a day; 3: several times/more than twice a day or always). A General Communication Composite (GCC, scales A+B+C+D+E+F+G+H, indicating overall communication functioning) and Social Interaction Deviance Composite (SIDC = (E+H+I+J) – (A+B+C+D); indicating a structural or pragmatic language impairment) can be derived from the scores. A GCC lower than 55 points towards probable ASD or SLI. A GCC lower than 55 and SIDC lower than 0 indicates a communicative style as seen in ASD, whereas a GCC lower than 55 and SIDC greater than 9 indicates SLI. A SIDC lower than -15 with a GCC in the normal range (> 55) is frequently seen in AS.

The tests take 10-15 minutes to complete. According to Bischop (2003), the reliability of the CCC is good (internal consistency α between .65 - .80; interrater agreement .16 - .79), as is the validity (validation studies with clinical groups).

*Table E.1*

*Scales and Domains of the Children's Communication Checklist*

| Scale | Domain |
|---|---|
| A: speech<br>B: syntax<br>C: semantics<br>D: coherence | Aspects of language structure |
| E: inappropriate initiation<br>F: stereotyped language<br>G: use of context<br>H: nonverbal communication | Pragmatic aspects of communication |
| I: social relations<br>J: interests | Usually impaired in ASD |

### E.2.2. Communication Checklist – Adult (CCA)

The Communication Checklist – Adult (CCA; Whitehouse & Bishop, 2009) is the equivalent of the CCC for adult participants. The tests differ in some items which have been reworded to be more adult appropriate. The 50 items of the CCA covering difficulties and 20 items covering strengths are grouped into three composite measures: language structure composite (scales A, B, C in CCC), pragmatic skills composite (verbal items from scales D, E, F, G, H, J in CCC), social engagement composite. Additionally, a global index of communicative and social competence can be obtained by computing a total raw score (TRS).

According to Whithouse and Bishop (2009) internal consistency (α) is high ranging between .91 and .97. Validation studies including participants with SLI, ASD and other showed that 90% of adults with a communication disorder scored less than the $20^{th}$ percentile on the TRS.

## Appendix F Certificate of Participation

The numbers on the certificate show the order of tasks in the assessments.

# CERTIFICATE

This is to certify that

______________________________

has taken part in our research project about

Language and Perception.

We completed the following tasks:

| | | | |
|---|---|---|---|
| Stories | 1 | 3 | |
| | 5 | 7 | |
| Words & Pictures | 2 | | |
| Sentences & Pictures | 4 | 6 | |

| | | | |
|---|---|---|---|
| Diamonds & Squares | 8 | 10 | 12 |
| | 14 | 16 | |
| Completion | 9 | | |
| Vocabulary | 11 | 15 | |
| Matrices | 13 | | |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Date

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# Appendix G Descriptive and Inferential Statistics in VISTA (Chapter 8)

## G.1. Descriptive Statistics

### G.1.1. TD participants

#### G.1.1.1. RT and accuracy in SHORT, LONG, MASK and contingencies

Table G.2

*RT data for TD participants (overall and split into age groups) in SHORT, LONG, MASK and contingencies*

| Block | Contingency | Level | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| All ages | | | | | | | | |
| SHORT | 20% | global | 67 | 478 | 1281 | 733 | 21 | 172 |
| | | local | 68 | 460 | 1510 | 778 | 27 | 219 |
| | | total | 67 | 483 | 1256 | 754 | 22 | 184 |
| | 50% | global | 68 | 417 | 1460 | 729 | 26 | 212 |
| | | local | 68 | 441 | 1467 | 784 | 29 | 241 |
| | | total | 68 | 429 | 1368 | 756 | 27 | 221 |
| | 80% | global | 68 | 407 | 1168 | 667 | 21 | 171 |
| | | local | 67 | 417 | 1318 | 691 | 22 | 181 |
| | | total | 67 | 412 | 1184 | 678 | 21 | 169 |
| LONG | | global | 47 | 498 | 1269 | 735 | 28 | 190 |
| | | local | 47 | 529 | 1411 | 767 | 31 | 213 |
| MASK | | global | 68 | 513 | 1288 | 778 | 24 | 197 |
| | | local | 68 | 532 | 1636 | 842 | 30 | 249 |
| Children | | | | | | | | |
| SHORT | 20% | global | 20 | 562 | 1281 | 897 | 36 | 162 |
| | | local | 21 | 674 | 1510 | 1001 | 48 | 218 |
| | | total | 20 | 714 | 1256 | 950 | 37 | 164 |
| | 50% | global | 21 | 651 | 1460 | 931 | 52 | 237 |
| | | local | 21 | 701 | 1467 | 1024 | 51 | 233 |
| | | total | 21 | 725 | 1368 | 978 | 48 | 221 |
| | 80% | global | 21 | 650 | 1168 | 841 | 37 | 171 |
| | | local | 20 | 449 | 1318 | 875 | 42 | 187 |
| | | total | 20 | 550 | 1184 | 859 | 36 | 160 |
| LONG | | global | 12 | 650 | 1269 | 956 | 54 | 187 |
| | | local | 12 | 652 | 1411 | 1001 | 66 | 230 |
| MASK | | global | 21 | 709 | 1288 | 984 | 40 | 181 |
| | | local | 21 | 736 | 1636 | 1095 | 51 | 232 |
| Adolescents | | | | | | | | |
| SHORT | 20% | global | 23 | 478 | 1014 | 676 | 26 | 125 |
| | | local | 23 | 531 | 905 | 714 | 24 | 114 |
| | | total | 23 | 508 | 955 | 695 | 23 | 109 |
| | 50% | global | 23 | 475 | 820 | 655 | 21 | 102 |
| | | local | 23 | 497 | 905 | 699 | 24 | 117 |
| | | total | 23 | 486 | 860 | 677 | 22 | 104 |
| | 80% | global | 23 | 429 | 787 | 598 | 17 | 82 |
| | | local | 23 | 447 | 827 | 628 | 21 | 103 |
| | | total | 23 | 462 | 779 | 613 | 19 | 90 |
| LONG | | global | 12 | 575 | 820 | 666 | 21 | 72 |
| | | local | 12 | 593 | 929 | 694 | 29 | 100 |
| MASK | | global | 23 | 545 | 1022 | 713 | 26 | 126 |
| | | local | 23 | 582 | 1145 | 776 | 37 | 179 |
| Adults | | | | | | | | |
| SHORT | 20% | global | 24 | 489 | 1044 | 650 | 25 | 120 |
| | | local | 24 | 460 | 1033 | 644 | 27 | 134 |
| | | total | 24 | 483 | 1039 | 647 | 25 | 122 |
| | 50% | global | 24 | 417 | 1081 | 622 | 27 | 133 |
| | | local | 24 | 441 | 1349 | 656 | 36 | 178 |
| | | total | 24 | 429 | 1215 | 639 | 31 | 154 |
| | 80% | global | 24 | 407 | 985 | 582 | 24 | 116 |
| | | local | 24 | 417 | 945 | 597 | 22 | 108 |
| | | total | 24 | 412 | 965 | 590 | 22 | 109 |
| LONG | | global | 23 | 498 | 1127 | 655 | 29 | 139 |
| | | local | 23 | 529 | 1144 | 684 | 32 | 154 |
| MASK | | global | 24 | 513 | 1014 | 659 | 21 | 105 |
| | | local | 24 | 532 | 935 | 684 | 24 | 118 |

Table G.3

*ACC data for TD participants (overall and split into age groups) in SHORT, LONG, MASK and contingencies*

| Block | Contingency | Level | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| All ages | | | | | | | | |
| SHORT | 20% | global | 67 | 68.8% | 100.0% | 94.1% | 1.0% | 7.8% |
| | | local | 68 | 56.3% | 100.0% | 93.8% | 1.1% | 9.0% |
| | 50% | global | 68 | 82.5% | 100.0% | 96.3% | 0.6% | 4.6% |
| | | local | 68 | 80.0% | 100.0% | 95.3% | 0.6% | 5.3% |
| | 80% | global | 68 | 85.9% | 100.0% | 96.7% | 0.4% | 3.7% |
| | | local | 67 | 70.3% | 100.0% | 96.4% | 0.6% | 5.3% |
| LONG | | global | 47 | 52.5% | 100.0% | 96.6% | 1.1% | 7.7% |
| | | local | 47 | 75.0% | 100.0% | 96.8% | 0.8% | 5.4% |
| MASK | | global | 68 | 70.0% | 100.0% | 94.4% | 0.8% | 6.7% |
| | | local | 68 | 55.0% | 100.0% | 93.1% | 1.3% | 10.8% |
| Children | | | | | | | | |
| SHORT | 20% | global | 20 | 68.8% | 100.0% | 90.3% | 2.4% | 10.6% |
| | | local | 21 | 75.0% | 100.0% | 93.2% | 1.8% | 8.4% |
| | 50% | global | 21 | 82.5% | 100.0% | 94.8% | 1.2% | 5.4% |
| | | local | 21 | 80.0% | 100.0% | 92.5% | 1.5% | 7.0% |
| | 80% | global | 21 | 85.9% | 100.0% | 95.9% | 0.9% | 4.0% |
| | | local | 20 | 70.3% | 100.0% | 93.5% | 1.8% | 7.9% |
| LONG | | global | 12 | 52.5% | 100.0% | 92.1% | 4.0% | 13.9% |
| | | local | 12 | 75.0% | 100.0% | 93.1% | 2.4% | 8.3% |
| MASK | | global | 21 | 70.0% | 100.0% | 91.4% | 2.0% | 9.3% |
| | | local | 21 | 55.0% | 100.0% | 86.2% | 3.1% | 14.4% |
| Adolescents | | | | | | | | |
| SHORT | 20% | global | 23 | 75.0% | 100.0% | 95.7% | 1.3% | 6.4% |
| | | local | 23 | 68.8% | 100.0% | 93.2% | 1.9% | 9.2% |
| | 50% | global | 23 | 85.0% | 100.0% | 96.6% | 1.0% | 4.6% |
| | | local | 23 | 85.0% | 100.0% | 96.3% | 0.8% | 3.9% |
| | 80% | global | 23 | 85.9% | 100.0% | 96.9% | 0.8% | 3.6% |
| | | local | 23 | 90.6% | 100.0% | 97.5% | 0.6% | 2.8% |
| LONG | | global | 12 | 92.5% | 100.0% | 98.3% | 0.8% | 2.7% |
| | | local | 12 | 85.0% | 100.0% | 98.1% | 1.3% | 4.4% |
| MASK | | global | 23 | 80.0% | 100.0% | 95.8% | 1.2% | 5.8% |
| | | local | 23 | 75.0% | 100.0% | 95.2% | 1.3% | 6.4% |
| Adults | | | | | | | | |
| SHORT | 20% | global | 24 | 87.5% | 100.0% | 95.9% | 1.0% | 5.1% |
| | | local | 24 | 56.3% | 100.0% | 94.8% | 1.9% | 9.5% |
| | 50% | global | 24 | 85.0% | 100.0% | 97.4% | 0.7% | 3.5% |
| | | local | 24 | 85.0% | 100.0% | 96.8% | 0.8% | 3.8% |
| | 80% | global | 24 | 85.9% | 100.0% | 97.2% | 0.7% | 3.5% |
| | | local | 24 | 87.5% | 100.0% | 97.7% | 0.7% | 3.3% |
| LONG | | global | 23 | 87.5% | 100.0% | 98.0% | 0.6% | 3.0% |
| | | local | 23 | 87.5% | 100.0% | 98.0% | 0.6% | 2.8% |
| MASK | | global | 24 | 87.5% | 100.0% | 95.8% | 0.7% | 3.7% |
| | | local | 24 | 65.0% | 100.0% | 97.0% | 1.6% | 7.8% |

### G.1.1.2. RT and accuracy for different priming conditions in SHORT, LONG, MASK and contingencies

Table G.4

*RT data for TD participants (over all age groups) for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 48 | 530 | 1453 | 784 | 31 | 218 |
| | | level-priming | 48 | 479 | 1209 | 730 | 26 | 179 |
| | | identity-priming | 48 | 454 | 1239 | 674 | 26 | 183 |
| | local | switch | 48 | 552 | 1419 | 806 | 31 | 215 |
| | | level-priming | 48 | 497 | 1810 | 770 | 36 | 249 |
| | | identity-priming | 48 | 464 | 1418 | 724 | 34 | 238 |
| | total | switch | 48 | 541 | 1436 | 795 | 30 | 211 |
| | | level-priming | 48 | 509 | 1410 | 750 | 29 | 203 |
| | | identity-priming | 48 | 476 | 1232 | 699 | 28 | 195 |
| | | nonswitch | 48 | 492 | 1249 | 725 | 28 | 192 |
| | global | PESC | 49 | -271 | 325 | 80 | 14 | 97 |
| | local | PESC | 49 | -261 | 182 | 61 | 11 | 79 |
| SHORT | global | switch | 67 | 479 | 1556 | 777 | 28 | 226 |
| | | level-priming | 67 | 413 | 1602 | 730 | 28 | 229 |
| | | identity-priming | 67 | 409 | 1431 | 699 | 25 | 204 |
| | local | switch | 67 | 497 | 1644 | 824 | 32 | 262 |
| | | level-priming | 67 | 425 | 1501 | 775 | 27 | 225 |
| | | identity-priming | 67 | 375 | 1516 | 742 | 28 | 231 |
| | total | switch | 67 | 488 | 1521 | 801 | 29 | 238 |
| | | level-priming | 67 | 419 | 1486 | 752 | 26 | 214 |
| | | identity-priming | 67 | 427 | 1287 | 721 | 26 | 209 |
| | | nonswitch | 67 | 423 | 1386 | 737 | 25 | 207 |
| | global | PESC | 68 | -122 | 302 | 62 | 9 | 74 |
| | local | PESC | 68 | -82 | 509 | 65 | 12 | 97 |
| MASK | global | switch | 66 | 514 | 1317 | 821 | 27 | 216 |
| | | level-priming | 66 | 504 | 2021 | 771 | 30 | 241 |
| | | identity-priming | 66 | 497 | 1486 | 741 | 26 | 212 |
| | local | switch | 66 | 563 | 1604 | 877 | 33 | 264 |
| | | level-priming | 66 | 514 | 1875 | 821 | 31 | 255 |
| | | identity-priming | 66 | 493 | 1637 | 835 | 34 | 274 |
| | total | switch | 66 | 539 | 1376 | 849 | 28 | 229 |
| | | level-priming | 66 | 535 | 1633 | 796 | 27 | 219 |
| | | identity-priming | 66 | 501 | 1561 | 788 | 28 | 231 |
| | global | PESC | 66 | -491 | 386 | 65 | 17 | 138 |
| | local | PESC | 66 | -221 | 301 | 49 | 13 | 105 |
| G20L80 | global | switch | 66 | 491 | 1603 | 769 | 26 | 210 |
| | | level-priming | 53 | 429 | 1378 | 734 | 29 | 210 |
| | | identity-priming | 53 | 428 | 1130 | 683 | 24 | 174 |
| | local | switch | 66 | 309 | 1313 | 762 | 26 | 208 |
| | | level-priming | 66 | 479 | 1455 | 699 | 22 | 183 |
| | | identity-priming | 66 | 428 | 1306 | 670 | 23 | 187 |
| G80L20 | global | switch | 67 | 458 | 1351 | 727 | 26 | 210 |
| | | level-priming | 67 | 430 | 1210 | 676 | 20 | 163 |
| | | identity-priming | 67 | 405 | 1163 | 637 | 20 | 168 |
| | local | switch | 67 | 479 | 1482 | 823 | 29 | 238 |
| | | level-priming | 54 | 412 | 1808 | 803 | 37 | 275 |
| | | identity-priming | 50 | 397 | 1891 | 689 | 33 | 235 |
| 80% contingency | total | switch | 67 | 478 | 1226 | 745 | 23 | 191 |
| | | level-priming | 67 | 471 | 1199 | 688 | 20 | 163 |
| | | identity-priming | 67 | 418 | 1189 | 654 | 21 | 171 |

Table G.5

*RT data for TD children for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 13 | 662 | 1453 | 1030 | 62 | 223 |
| | | level-priming | 13 | 640 | 1163 | 905 | 51 | 184 |
| | | identity-priming | 13 | 633 | 1143 | 836 | 44 | 159 |
| | local | switch | 13 | 717 | 1419 | 1045 | 53 | 192 |
| | | level-priming | 13 | 649 | 1810 | 1015 | 85 | 305 |
| | | identity-priming | 13 | 585 | 1368 | 912 | 68 | 246 |
| | total | switch | 13 | 689 | 1436 | 1037 | 54 | 196 |
| | | level-priming | 13 | 644 | 1410 | 960 | 62 | 223 |
| | | identity-priming | 13 | 625 | 1232 | 874 | 52 | 187 |
| | | nonswitch | 13 | 635 | 1249 | 917 | 54 | 196 |
| | global | PESC | 14 | 22 | 325 | 153 | 25 | 92 |
| | local | PESC | 14 | -105 | 181 | 79 | 21 | 78 |
| SHORT | global | switch | 21 | 708 | 1556 | 983 | 56 | 255 |
| | | level-priming | 21 | 677 | 1602 | 922 | 61 | 282 |
| | | identity-priming | 21 | 640 | 1431 | 894 | 46 | 213 |
| | local | switch | 21 | 718 | 1644 | 1062 | 58 | 264 |
| | | level-priming | 21 | 632 | 1501 | 987 | 49 | 226 |
| | | identity-priming | 21 | 651 | 1516 | 983 | 53 | 242 |
| | total | switch | 21 | 747 | 1521 | 1023 | 54 | 247 |
| | | level-priming | 21 | 656 | 1486 | 954 | 50 | 230 |
| | | identity-priming | 21 | 665 | 1287 | 938 | 46 | 209 |
| | | nonswitch | 21 | 738 | 1386 | 946 | 46 | 211 |
| | global | PESC | 21 | -35 | 302 | 75 | 17 | 78 |
| | local | PESC | 21 | -82 | 509 | 78 | 27 | 122 |
| MASK | global | switch | 20 | 702 | 1317 | 1064 | 39 | 173 |
| | | level-priming | 20 | 666 | 2021 | 975 | 71 | 317 |
| | | identity-priming | 20 | 684 | 1486 | 948 | 45 | 202 |
| | local | switch | 20 | 756 | 1604 | 1161 | 51 | 227 |
| | | level-priming | 20 | 691 | 1875 | 1052 | 64 | 284 |
| | | identity-priming | 20 | 769 | 1637 | 1102 | 60 | 269 |
| | total | switch | 20 | 847 | 1376 | 1113 | 36 | 163 |
| | | level-priming | 20 | 725 | 1633 | 1014 | 51 | 228 |
| | | identity-priming | 20 | 735 | 1561 | 1025 | 48 | 215 |
| | global | PESC | 20 | -491 | 386 | 103 | 49 | 217 |
| | local | PESC | 20 | -135 | 301 | 84 | 33 | 146 |
| G20L80 | global | switch | 20 | 562 | 1422 | 934 | 42 | 187 |
| | | level-priming | 15 | 673 | 1378 | 952 | 53 | 204 |
| | | identity-priming | 13 | 652 | 1130 | 844 | 46 | 166 |
| | local | switch | 20 | 309 | 1313 | 931 | 51 | 230 |
| | | level-priming | 20 | 562 | 1455 | 886 | 43 | 194 |
| | | identity-priming | 20 | 463 | 1306 | 855 | 44 | 198 |
| G80L20 | global | switch | 21 | 633 | 1351 | 922 | 49 | 224 |
| | | level-priming | 21 | 634 | 1210 | 832 | 37 | 169 |
| | | identity-priming | 21 | 590 | 1163 | 803 | 35 | 161 |
| | local | switch | 21 | 664 | 1482 | 1048 | 51 | 234 |
| | | level-priming | 18 | 725 | 1808 | 1071 | 66 | 280 |
| | | identity-priming | 14 | 514 | 1891 | 796 | 93 | 349 |
| 80% contingency | total | switch | 21 | 538 | 1226 | 924 | 40 | 182 |
| | | level-priming | 21 | 598 | 1199 | 857 | 34 | 154 |
| | | identity-priming | 21 | 541 | 1189 | 826 | 36 | 166 |

Table G.6

*RT data for TD adolescents for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 12 | 563 | 908 | 702 | 27 | 92 |
| | | level-priming | 12 | 515 | 820 | 659 | 27 | 94 |
| | | identity-priming | 12 | 552 | 1239 | 661 | 55 | 191 |
| | local | switch | 12 | 600 | 1095 | 731 | 41 | 141 |
| | | level-priming | 12 | 553 | 1140 | 700 | 45 | 156 |
| | | identity-priming | 12 | 533 | 839 | 636 | 24 | 83 |
| | total | switch | 12 | 606 | 1002 | 716 | 32 | 112 |
| | | level-priming | 12 | 569 | 980 | 680 | 32 | 111 |
| | | identity-priming | 12 | 546 | 1039 | 648 | 39 | 134 |
| | | nonswitch | 12 | 577 | 904 | 664 | 30 | 105 |
| | global | PESC | 12 | -271 | 137 | 34 | 33 | 115 |
| | local | PESC | 12 | -11 | 182 | 73 | 18 | 62 |
| SHORT | global | switch | 23 | 496 | 906 | 687 | 24 | 116 |
| | | level-priming | 23 | 463 | 903 | 665 | 23 | 112 |
| | | identity-priming | 23 | 452 | 844 | 633 | 22 | 105 |
| | local | switch | 23 | 545 | 961 | 719 | 28 | 132 |
| | | level-priming | 23 | 496 | 989 | 693 | 25 | 118 |
| | | identity-priming | 23 | 463 | 872 | 664 | 23 | 111 |
| | total | switch | 23 | 521 | 915 | 703 | 25 | 120 |
| | | level-priming | 23 | 480 | 886 | 679 | 21 | 99 |
| | | identity-priming | 23 | 457 | 839 | 648 | 21 | 99 |
| | | nonswitch | 23 | 468 | 853 | 664 | 20 | 95 |
| | global | PESC | 23 | -122 | 217 | 38 | 16 | 79 |
| | local | PESC | 23 | -56 | 160 | 40 | 13 | 61 |
| MASK | global | switch | 23 | 545 | 992 | 739 | 30 | 144 |
| | | level-priming | 23 | 540 | 1026 | 713 | 27 | 128 |
| | | identity-priming | 23 | 505 | 1380 | 688 | 37 | 177 |
| | local | switch | 23 | 585 | 1295 | 798 | 42 | 203 |
| | | level-priming | 23 | 531 | 1163 | 759 | 38 | 185 |
| | | identity-priming | 23 | 568 | 1133 | 762 | 36 | 174 |
| | total | switch | 23 | 568 | 1135 | 768 | 35 | 167 |
| | | level-priming | 23 | 535 | 1068 | 736 | 30 | 144 |
| | | identity-priming | 23 | 541 | 1256 | 725 | 34 | 164 |
| | global | PESC | 23 | -228 | 248 | 39 | 21 | 99 |
| | local | PESC | 23 | -121 | 266 | 38 | 18 | 85 |
| G20L80 | global | switch | 23 | 491 | 1058 | 692 | 28 | 133 |
| | | level-priming | 18 | 480 | 809 | 648 | 24 | 103 |
| | | identity-priming | 20 | 428 | 982 | 646 | 37 | 165 |
| | local | switch | 23 | 475 | 1155 | 702 | 31 | 149 |
| | | level-priming | 23 | 479 | 828 | 629 | 20 | 97 |
| | | identity-priming | 23 | 430 | 781 | 601 | 24 | 114 |
| G80L20 | global | switch | 23 | 463 | 781 | 642 | 18 | 88 |
| | | level-priming | 23 | 446 | 804 | 609 | 18 | 87 |
| | | identity-priming | 23 | 405 | 811 | 568 | 20 | 95 |
| | local | switch | 23 | 532 | 968 | 737 | 25 | 119 |
| | | level-priming | 19 | 463 | 1026 | 709 | 32 | 141 |
| | | identity-priming | 16 | 397 | 1043 | 665 | 46 | 185 |
| 80% contingency | total | switch | 23 | 478 | 957 | 672 | 24 | 113 |
| | | level-priming | 23 | 471 | 777 | 619 | 18 | 87 |
| | | identity-priming | 23 | 428 | 791 | 585 | 21 | 100 |

Table G.7

*RT data for TD adults for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 23 | 530 | 1109 | 689 | 30 | 145 |
| | | level-priming | 23 | 479 | 1209 | 668 | 30 | 144 |
| | | identity-priming | 23 | 454 | 961 | 590 | 27 | 130 |
| | local | switch | 23 | 552 | 1042 | 710 | 31 | 148 |
| | | level-priming | 23 | 497 | 1186 | 668 | 30 | 144 |
| | | identity-priming | 23 | 464 | 1418 | 663 | 49 | 236 |
| | total | switch | 23 | 541 | 1075 | 699 | 30 | 142 |
| | | level-priming | 23 | 509 | 1198 | 668 | 29 | 139 |
| | | identity-priming | 23 | 476 | 1183 | 627 | 35 | 169 |
| | | nonswitch | 23 | 492 | 1190 | 647 | 31 | 150 |
| | global | PESC | 23 | -47 | 225 | 60 | 13 | 65 |
| | local | PESC | 23 | -261 | 152 | 44 | 18 | 88 |
| SHORT | global | switch | 23 | 479 | 1129 | 680 | 31 | 147 |
| | | level-priming | 23 | 413 | 1042 | 619 | 29 | 140 |
| | | identity-priming | 23 | 409 | 1009 | 587 | 29 | 138 |
| | local | switch | 23 | 497 | 1551 | 713 | 45 | 215 |
| | | level-priming | 23 | 425 | 1292 | 663 | 35 | 169 |
| | | identity-priming | 23 | 375 | 952 | 602 | 23 | 111 |
| | total | switch | 23 | 488 | 1340 | 696 | 37 | 176 |
| | | level-priming | 23 | 419 | 1167 | 641 | 31 | 150 |
| | | identity-priming | 23 | 427 | 981 | 594 | 25 | 121 |
| | | nonswitch | 23 | 423 | 1074 | 618 | 27 | 131 |
| | global | PESC | 24 | -11 | 262 | 73 | 13 | 62 |
| | local | PESC | 24 | -35 | 429 | 79 | 20 | 100 |
| MASK | global | switch | 23 | 514 | 1001 | 692 | 23 | 110 |
| | | level-priming | 23 | 504 | 1088 | 651 | 24 | 114 |
| | | identity-priming | 23 | 497 | 876 | 615 | 19 | 89 |
| | local | switch | 23 | 563 | 939 | 708 | 22 | 105 |
| | | level-priming | 23 | 514 | 932 | 681 | 25 | 120 |
| | | identity-priming | 23 | 493 | 1280 | 677 | 37 | 178 |
| | total | switch | 23 | 539 | 922 | 700 | 21 | 102 |
| | | level-priming | 23 | 541 | 1010 | 666 | 22 | 105 |
| | | identity-priming | 23 | 501 | 963 | 646 | 26 | 123 |
| | global | PESC | 23 | -38 | 163 | 59 | 12 | 58 |
| | local | PESC | 23 | -221 | 142 | 29 | 15 | 71 |
| G20L80 | global | switch | 23 | 513 | 1603 | 704 | 46 | 219 |
| | | level-priming | 20 | 429 | 1020 | 647 | 37 | 167 |
| | | identity-priming | 20 | 438 | 897 | 617 | 26 | 118 |
| | local | switch | 23 | 496 | 1145 | 675 | 31 | 147 |
| | | level-priming | 23 | 480 | 960 | 606 | 21 | 103 |
| | | identity-priming | 23 | 428 | 907 | 579 | 22 | 107 |
| G80L20 | global | switch | 23 | 458 | 1274 | 635 | 34 | 163 |
| | | level-priming | 23 | 430 | 982 | 601 | 23 | 111 |
| | | identity-priming | 23 | 408 | 983 | 553 | 24 | 114 |
| | local | switch | 23 | 479 | 1300 | 705 | 39 | 189 |
| | | level-priming | 17 | 412 | 1007 | 624 | 34 | 140 |
| | | identity-priming | 20 | 462 | 1007 | 633 | 32 | 143 |
| 80% contingency | total | switch | 23 | 484 | 1209 | 655 | 31 | 147 |
| | | level-priming | 23 | 471 | 971 | 604 | 21 | 102 |
| | | identity-priming | 23 | 418 | 945 | 566 | 22 | 105 |

Table G.8

*ACC data for TD participants (over all age groups) for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 48 | 66.7% | 100.0% | 95.1% | 1.0% | 6.8% |
| | | level-priming | 48 | 76.9% | 100.0% | 96.8% | 0.8% | 5.8% |
| | | identity-priming | 48 | 80.0% | 100.0% | 99.1% | 0.6% | 3.9% |
| | local | switch | 48 | 76.2% | 100.0% | 95.7% | 0.9% | 6.4% |
| | | level-priming | 48 | 57.1% | 100.0% | 96.4% | 1.2% | 8.1% |
| | | identity-priming | 48 | 81.8% | 100.0% | 98.3% | 0.7% | 4.8% |
| | total | switch | 48 | 74.0% | 100.0% | 95.4% | 0.9% | 6.0% |
| | | level-priming | 48 | 73.6% | 100.0% | 96.6% | 0.8% | 5.3% |
| | | identity-priming | 48 | 86.7% | 100.0% | 98.7% | 0.5% | 3.2% |
| | global | PESC | 48 | -11.9% | 22.7% | 2.8% | 0.9% | 6.3% |
| | local | PESC | 48 | -16.5% | 23.8% | 1.6% | 1.0% | 6.7% |
| SHORT | global | switch | 67 | 77.8% | 100.0% | 93.0% | 0.8% | 6.3% |
| | | level-priming | 67 | 77.8% | 100.0% | 96.3% | 0.8% | 6.4% |
| | | identity-priming | 67 | 72.7% | 100.0% | 96.3% | 0.7% | 6.0% |
| | local | switch | 67 | 44.4% | 100.0% | 91.4% | 1.4% | 11.4% |
| | | level-priming | 67 | 47.8% | 100.0% | 93.2% | 1.2% | 10.2% |
| | | identity-priming | 67 | 40.0% | 100.0% | 94.1% | 1.4% | 11.4% |
| | total | switch | 67 | 68.1% | 100.0% | 92.2% | 0.8% | 6.9% |
| | | level-priming | 67 | 72.0% | 100.0% | 94.8% | 0.7% | 5.7% |
| | | identity-priming | 67 | 65.0% | 100.0% | 95.2% | 0.9% | 7.1% |
| | global | PESC | 68 | -11.0% | 17.2% | 3.1% | 0.8% | 6.3% |
| | local | PESC | 68 | -12.5% | 22.2% | 2.2% | 0.9% | 7.5% |
| MASK | global | switch | 66 | 58.3% | 100.0% | 91.6% | 1.0% | 8.5% |
| | | level-priming | 66 | 33.3% | 100.0% | 94.5% | 1.3% | 10.5% |
| | | identity-priming | 66 | 33.3% | 100.0% | 94.2% | 1.4% | 11.4% |
| | local | switch | 66 | 50.0% | 100.0% | 89.0% | 1.6% | 12.6% |
| | | level-priming | 66 | 50.0% | 100.0% | 92.8% | 1.5% | 11.8% |
| | | identity-priming | 66 | 45.5% | 100.0% | 93.6% | 1.5% | 12.6% |
| | total | switch | 66 | 63.9% | 100.0% | 90.3% | 1.0% | 8.2% |
| | | level-priming | 66 | 66.7% | 100.0% | 93.7% | 1.0% | 8.5% |
| | | identity-priming | 66 | 59.5% | 100.0% | 93.9% | 1.2% | 9.8% |
| | global | PESC | 66 | -32.1% | 34.5% | 2.8% | 1.2% | 10.1% |
| | local | PESC | 66 | -13.7% | 28.9% | 4.2% | 1.1% | 8.9% |
| G20L80 | global | switch | 66 | 50.0% | 100.0% | 91.1% | 1.4% | 11.0% |
| | | level-priming | 53 | 50.0% | 100.0% | 97.2% | 1.5% | 10.6% |
| | | identity-priming | 53 | 50.0% | 100.0% | 98.4% | 1.1% | 8.2% |
| | local | switch | 66 | 20.0% | 100.0% | 93.2% | 1.6% | 13.0% |
| | | level-priming | 66 | 42.9% | 100.0% | 94.9% | 1.1% | 8.9% |
| | | identity-priming | 66 | 55.0% | 100.0% | 96.2% | 0.9% | 7.2% |
| G80L20 | global | switch | 67 | 76.9% | 100.0% | 94.2% | 0.8% | 6.6% |
| | | level-priming | 67 | 77.3% | 100.0% | 95.8% | 0.6% | 5.0% |
| | | identity-priming | 67 | 85.2% | 100.0% | 96.8% | 0.5% | 4.1% |
| | local | switch | 67 | 53.3% | 100.0% | 91.6% | 1.3% | 11.0% |
| | | level-priming | 54 | 50.0% | 100.0% | 96.5% | 1.4% | 10.2% |
| | | identity-priming | 50 | 87.5% | 100.0% | 99.8% | 0.3% | 1.8% |
| 80% contingency | total | switch | 67 | 60.0% | 100.0% | 93.7% | 0.9% | 7.5% |
| | | level-priming | 67 | 71.4% | 100.0% | 95.3% | 0.6% | 5.1% |
| | | identity-priming | 67 | 77.5% | 100.0% | 96.5% | 0.5% | 4.5% |

Table G.9

*ACC data for TD children for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 13 | 66.7% | 100.0% | 90.8% | 2.7% | 9.7% |
| | | level-priming | 13 | 90.0% | 100.0% | 97.5% | 1.1% | 3.9% |
| | | identity-priming | 13 | 80.0% | 100.0% | 97.2% | 1.9% | 6.9% |
| | local | switch | 13 | 81.3% | 100.0% | 94.4% | 2.1% | 7.6% |
| | | level-priming | 13 | 57.1% | 100.0% | 93.1% | 3.7% | 13.4% |
| | | identity-priming | 13 | 81.8% | 100.0% | 95.9% | 1.9% | 6.9% |
| | total | switch | 13 | 74.0% | 100.0% | 92.6% | 2.2% | 8.1% |
| | | level-priming | 13 | 73.6% | 100.0% | 95.3% | 2.2% | 8.1% |
| | | identity-priming | 13 | 86.7% | 100.0% | 96.5% | 1.4% | 4.9% |
| | global | PESC | 13 | -3.8% | 22.7% | 6.5% | 2.2% | 8.0% |
| | local | PESC | 13 | -16.5% | 11.7% | 0.1% | 2.3% | 8.1% |
| SHORT | global | switch | 21 | 77.8% | 100.0% | 91.5% | 1.3% | 6.0% |
| | | level-priming | 21 | 80.0% | 100.0% | 96.6% | 1.4% | 6.3% |
| | | identity-priming | 21 | 72.7% | 100.0% | 93.6% | 1.7% | 7.9% |
| | local | switch | 21 | 44.4% | 100.0% | 85.2% | 3.4% | 15.7% |
| | | level-priming | 21 | 47.8% | 100.0% | 88.3% | 3.3% | 15.2% |
| | | identity-priming | 21 | 40.0% | 100.0% | 88.0% | 3.7% | 16.7% |
| | total | switch | 21 | 68.1% | 100.0% | 88.3% | 1.9% | 8.8% |
| | | level-priming | 21 | 72.0% | 100.0% | 92.5% | 1.6% | 7.6% |
| | | identity-priming | 21 | 65.0% | 100.0% | 90.8% | 2.1% | 9.7% |
| | global | PESC | 21 | -8.4% | 13.0% | 3.6% | 1.4% | 6.3% |
| | local | PESC | 21 | -12.5% | 22.2% | 3.0% | 2.1% | 9.6% |
| MASK | global | switch | 20 | 58.3% | 100.0% | 88.2% | 2.5% | 11.3% |
| | | level-priming | 20 | 33.3% | 100.0% | 90.2% | 3.5% | 15.4% |
| | | identity-priming | 20 | 50.0% | 100.0% | 91.4% | 2.7% | 12.1% |
| | local | switch | 20 | 50.0% | 100.0% | 81.8% | 3.5% | 15.6% |
| | | level-priming | 20 | 66.7% | 100.0% | 87.4% | 3.1% | 13.9% |
| | | identity-priming | 20 | 45.5% | 100.0% | 85.8% | 4.0% | 18.1% |
| | total | switch | 20 | 63.9% | 97.5% | 85.0% | 2.1% | 9.4% |
| | | level-priming | 20 | 66.7% | 100.0% | 88.8% | 2.1% | 9.5% |
| | | identity-priming | 20 | 60.0% | 100.0% | 88.6% | 2.7% | 12.1% |
| | global | PESC | 20 | -20.8% | 34.5% | 2.6% | 2.6% | 11.7% |
| | local | PESC | 20 | -13.7% | 28.9% | 4.8% | 2.8% | 12.6% |
| G20L80 | global | switch | 20 | 69.2% | 100.0% | 87.8% | 2.6% | 11.7% |
| | | level-priming | 15 | 50.0% | 100.0% | 95.0% | 3.6% | 14.0% |
| | | identity-priming | 13 | 66.7% | 100.0% | 97.4% | 2.6% | 9.2% |
| | local | switch | 20 | 20.0% | 100.0% | 86.7% | 4.6% | 20.4% |
| | | level-priming | 20 | 42.9% | 100.0% | 89.4% | 3.1% | 14.0% |
| | | identity-priming | 20 | 55.0% | 100.0% | 92.9% | 2.5% | 11.0% |
| G80L20 | global | switch | 21 | 76.9% | 100.0% | 90.5% | 1.5% | 6.7% |
| | | level-priming | 21 | 85.0% | 100.0% | 95.8% | 0.9% | 4.0% |
| | | identity-priming | 21 | 85.2% | 100.0% | 94.7% | 1.1% | 4.8% |
| | local | switch | 21 | 69.2% | 100.0% | 90.4% | 2.2% | 10.2% |
| | | level-priming | 18 | 66.7% | 100.0% | 98.1% | 1.9% | 7.9% |
| | | identity-priming | 14 | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% |
| 80% contingency | total | switch | 21 | 60.0% | 100.0% | 88.6% | 2.1% | 9.5% |
| | | level-priming | 21 | 71.4% | 100.0% | 92.7% | 1.5% | 7.1% |
| | | identity-priming | 21 | 77.5% | 100.0% | 93.9% | 1.3% | 6.0% |

Table G.10

*ACC data for TD adolescents for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 12 | 85.7% | 100.0% | 94.7% | 1.5% | 5.1% |
| | | level-priming | 12 | 76.9% | 100.0% | 96.5% | 2.1% | 7.1% |
| | | identity-priming | 12 | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% |
| | local | switch | 12 | 78.6% | 100.0% | 94.8% | 1.9% | 6.6% |
| | | level-priming | 12 | 84.6% | 100.0% | 96.8% | 1.5% | 5.2% |
| | | identity-priming | 12 | 84.6% | 100.0% | 98.7% | 1.3% | 4.4% |
| | total | switch | 12 | 82.1% | 100.0% | 94.8% | 1.6% | 5.7% |
| | | level-priming | 12 | 84.6% | 100.0% | 96.7% | 1.4% | 4.9% |
| | | identity-priming | 12 | 92.3% | 100.0% | 99.4% | 0.6% | 2.2% |
| | global | PESC | 12 | -5.0% | 14.3% | 3.6% | 1.4% | 5.0% |
| | local | PESC | 12 | -1.1% | 17.6% | 2.9% | 1.5% | 5.2% |
| SHORT | global | switch | 23 | 77.8% | 100.0% | 92.8% | 1.5% | 7.2% |
| | | level-priming | 23 | 77.8% | 100.0% | 95.3% | 1.5% | 7.1% |
| | | identity-priming | 23 | 83.3% | 100.0% | 96.4% | 1.0% | 4.9% |
| | local | switch | 23 | 79.2% | 100.0% | 94.3% | 1.2% | 5.9% |
| | | level-priming | 23 | 83.3% | 100.0% | 95.5% | 1.3% | 6.1% |
| | | identity-priming | 23 | 86.0% | 100.0% | 97.0% | 0.9% | 4.2% |
| | total | switch | 23 | 83.3% | 100.0% | 93.5% | 1.1% | 5.1% |
| | | level-priming | 23 | 88.2% | 100.0% | 95.4% | 0.9% | 4.3% |
| | | identity-priming | 23 | 86.7% | 100.0% | 96.7% | 0.8% | 4.1% |
| | global | PESC | 23 | -11.0% | 17.2% | 3.0% | 1.5% | 7.0% |
| | local | PESC | 23 | -10.0% | 19.0% | 2.0% | 1.5% | 7.1% |
| MASK | global | switch | 23 | 68.8% | 100.0% | 93.6% | 1.6% | 7.7% |
| | | level-priming | 23 | 71.4% | 100.0% | 96.1% | 1.6% | 7.6% |
| | | identity-priming | 23 | 33.3% | 100.0% | 94.3% | 3.0% | 14.5% |
| | local | switch | 23 | 61.9% | 100.0% | 91.7% | 1.8% | 8.8% |
| | | level-priming | 23 | 76.9% | 100.0% | 95.2% | 1.5% | 7.4% |
| | | identity-priming | 23 | 81.8% | 100.0% | 97.6% | 1.1% | 5.4% |
| | total | switch | 23 | 76.2% | 100.0% | 92.6% | 1.2% | 5.9% |
| | | level-priming | 23 | 80.7% | 100.0% | 95.7% | 1.2% | 5.7% |
| | | identity-priming | 23 | 59.5% | 100.0% | 96.0% | 1.9% | 9.1% |
| | global | PESC | 23 | -32.1% | 24.6% | 1.6% | 2.3% | 11.1% |
| | local | PESC | 23 | -6.6% | 26.8% | 4.8% | 1.4% | 6.9% |
| G20L80 | global | switch | 23 | 66.7% | 100.0% | 93.1% | 2.0% | 9.7% |
| | | level-priming | 18 | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% |
| | | identity-priming | 20 | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% |
| | local | switch | 23 | 76.9% | 100.0% | 95.6% | 1.4% | 6.5% |
| | | level-priming | 23 | 87.5% | 100.0% | 96.8% | 0.7% | 3.5% |
| | | identity-priming | 23 | 86.7% | 100.0% | 98.0% | 0.8% | 3.7% |
| G80L20 | global | switch | 23 | 78.6% | 100.0% | 95.1% | 1.4% | 6.5% |
| | | level-priming | 23 | 77.3% | 100.0% | 96.2% | 1.2% | 5.9% |
| | | identity-priming | 23 | 86.4% | 100.0% | 96.9% | 0.8% | 4.0% |
| | local | switch | 23 | 58.3% | 100.0% | 91.7% | 2.4% | 11.5% |
| | | level-priming | 19 | 50.0% | 100.0% | 93.4% | 3.3% | 14.3% |
| | | identity-priming | 16 | 87.5% | 100.0% | 99.2% | 0.8% | 3.1% |
| 80% contingency | total | switch | 23 | 84.3% | 100.0% | 95.3% | 1.1% | 5.2% |
| | | level-priming | 23 | 86.9% | 100.0% | 96.5% | 0.8% | 3.6% |
| | | identity-priming | 23 | 88.3% | 100.0% | 97.4% | 0.7% | 3.3% |

Table G.11

*ACC data for TD adults for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 23 | 85.7% | 100.0% | 97.8% | 0.8% | 3.9% |
| | | level-priming | 23 | 81.8% | 100.0% | 96.6% | 1.3% | 6.1% |
| | | identity-priming | 23 | 91.7% | 100.0% | 99.6% | 0.4% | 1.7% |
| | local | switch | 23 | 76.2% | 100.0% | 97.0% | 1.1% | 5.4% |
| | | level-priming | 23 | 83.3% | 100.0% | 98.1% | 1.0% | 4.6% |
| | | identity-priming | 23 | 85.7% | 100.0% | 99.4% | 0.6% | 3.0% |
| | total | switch | 23 | 81.0% | 100.0% | 97.4% | 0.8% | 4.1% |
| | | level-priming | 23 | 90.9% | 100.0% | 97.3% | 0.7% | 3.3% |
| | | identity-priming | 23 | 92.9% | 100.0% | 99.5% | 0.4% | 1.7% |
| | global | PESC | 23 | -11.9% | 9.1% | 0.3% | 1.0% | 4.7% |
| | local | PESC | 23 | -8.3% | 23.8% | 1.7% | 1.4% | 6.5% |
| SHORT | global | switch | 23 | 82.4% | 100.0% | 94.6% | 1.1% | 5.5% |
| | | level-priming | 23 | 80.0% | 100.0% | 97.1% | 1.2% | 5.9% |
| | | identity-priming | 23 | 87.5% | 100.0% | 98.6% | 0.8% | 3.9% |
| | local | switch | 23 | 61.5% | 100.0% | 94.1% | 1.8% | 8.9% |
| | | level-priming | 23 | 84.6% | 100.0% | 95.5% | 1.2% | 5.6% |
| | | identity-priming | 23 | 69.2% | 100.0% | 96.8% | 1.7% | 8.0% |
| | total | switch | 23 | 80.8% | 100.0% | 94.3% | 1.1% | 5.2% |
| | | level-priming | 23 | 82.9% | 100.0% | 96.3% | 0.9% | 4.3% |
| | | identity-priming | 23 | 83.0% | 100.0% | 97.7% | 1.0% | 4.9% |
| | global | PESC | 24 | -8.0% | 14.3% | 2.8% | 1.2% | 5.7% |
| | local | PESC | 24 | -8.0% | 16.7% | 1.6% | 1.2% | 5.9% |
| MASK | global | switch | 23 | 81.3% | 100.0% | 92.5% | 1.1% | 5.4% |
| | | level-priming | 23 | 81.8% | 100.0% | 96.7% | 1.3% | 6.1% |
| | | identity-priming | 23 | 76.9% | 100.0% | 96.5% | 1.3% | 6.1% |
| | local | switch | 23 | 60.0% | 100.0% | 92.8% | 2.2% | 10.7% |
| | | level-priming | 23 | 50.0% | 100.0% | 95.2% | 2.6% | 12.3% |
| | | identity-priming | 23 | 70.0% | 100.0% | 96.3% | 1.8% | 8.7% |
| | total | switch | 23 | 74.7% | 100.0% | 92.6% | 1.4% | 6.9% |
| | | level-priming | 23 | 67.3% | 100.0% | 95.9% | 1.8% | 8.4% |
| | | identity-priming | 23 | 76.0% | 100.0% | 96.4% | 1.3% | 6.4% |
| | global | PESC | 23 | -11.5% | 18.8% | 4.1% | 1.6% | 7.5% |
| | local | PESC | 23 | -8.9% | 21.4% | 3.0% | 1.4% | 6.9% |
| G20L80 | global | switch | 23 | 50.0% | 100.0% | 92.1% | 2.4% | 11.4% |
| | | level-priming | 20 | 50.0% | 100.0% | 96.3% | 2.7% | 12.2% |
| | | identity-priming | 20 | 50.0% | 100.0% | 97.5% | 2.5% | 11.2% |
| | local | switch | 23 | 78.6% | 100.0% | 96.5% | 1.3% | 6.4% |
| | | level-priming | 23 | 87.1% | 100.0% | 97.8% | 0.7% | 3.3% |
| | | identity-priming | 23 | 80.0% | 100.0% | 97.3% | 0.9% | 4.4% |
| G80L20 | global | switch | 23 | 84.6% | 100.0% | 96.8% | 1.1% | 5.3% |
| | | level-priming | 23 | 80.0% | 100.0% | 95.4% | 1.0% | 4.9% |
| | | identity-priming | 23 | 93.1% | 100.0% | 98.8% | 0.5% | 2.2% |
| | local | switch | 23 | 53.3% | 100.0% | 92.5% | 2.4% | 11.6% |
| | | level-priming | 17 | 83.3% | 100.0% | 98.0% | 1.3% | 5.5% |
| | | identity-priming | 20 | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% |
| 80% contingency | total | switch | 23 | 82.6% | 100.0% | 96.6% | 1.0% | 4.9% |
| | | level-priming | 23 | 87.8% | 100.0% | 96.6% | 0.7% | 3.1% |
| | | identity-priming | 23 | 88.1% | 100.0% | 98.1% | 0.5% | 2.5% |

### G.1.1.3. BI data for TD depending on age group and AQ group

Table G.12

*BIRT and BIACC for TD participants (overall and split into age groups)*

| | Block | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|
| All age groups | | | | | | | |
| BIRT | G20L80 | 67 | 0.69 | 1.33 | 1.07 | 0.01 | 0.12 |
| | G50L50 | 68 | 0.71 | 1.15 | 0.94 | 0.01 | 0.10 |
| | G80L20 | 68 | 0.55 | 1.21 | 0.87 | 0.01 | 0.11 |
| | LONG | 47 | 0.73 | 1.10 | 0.96 | 0.01 | 0.09 |
| | MASK | 68 | 0.49 | 1.25 | 0.94 | 0.01 | 0.12 |
| BIACC | G20L80 | 67 | 0.89 | 1.27 | 1.03 | 0.01 | 0.07 |
| | G50L50 | 68 | 0.84 | 1.09 | 0.99 | 0.01 | 0.05 |
| | G80L20 | 68 | 0.62 | 1.09 | 0.97 | 0.01 | 0.08 |
| | LONG | 47 | 0.92 | 1.43 | 1.01 | 0.01 | 0.07 |
| | MASK | 68 | 0.58 | 1.30 | 0.99 | 0.01 | 0.10 |
| Children | | | | | | | |
| BIRT | G20L80 | 20 | 0.69 | 1.32 | 1.04 | 0.03 | 0.15 |
| | G50L50 | 21 | 0.71 | 1.15 | 0.92 | 0.03 | 0.14 |
| | G80L20 | 21 | 0.55 | 1.21 | 0.85 | 0.03 | 0.15 |
| | LONG | 12 | 0.74 | 1.08 | 0.97 | 0.03 | 0.10 |
| | MASK | 21 | 0.49 | 1.25 | 0.92 | 0.04 | 0.18 |
| BIACC | G20L80 | 20 | 0.89 | 1.27 | 1.04 | 0.02 | 0.09 |
| | G50L50 | 21 | 0.84 | 1.09 | 0.98 | 0.01 | 0.07 |
| | G80L20 | 21 | 0.77 | 1.09 | 0.97 | 0.02 | 0.08 |
| | LONG | 12 | 0.92 | 1.43 | 1.03 | 0.04 | 0.13 |
| | MASK | 21 | 0.58 | 1.30 | 0.95 | 0.03 | 0.15 |
| Adolescents | | | | | | | |
| BIRT | G20L80 | 23 | 0.92 | 1.33 | 1.08 | 0.02 | 0.11 |
| | G50L50 | 23 | 0.76 | 1.13 | 0.94 | 0.02 | 0.09 |
| | G80L20 | 23 | 0.73 | 1.06 | 0.84 | 0.02 | 0.08 |
| | LONG | 12 | 0.80 | 1.10 | 0.97 | 0.02 | 0.08 |
| | MASK | 23 | 0.72 | 1.07 | 0.93 | 0.02 | 0.08 |
| BIACC | G20L80 | 23 | 0.91 | 1.23 | 1.02 | 0.01 | 0.07 |
| | G50L50 | 23 | 0.92 | 1.09 | 1.00 | 0.01 | 0.04 |
| | G80L20 | 23 | 0.80 | 1.07 | 0.96 | 0.02 | 0.08 |
| | LONG | 12 | 0.92 | 1.05 | 1.00 | 0.01 | 0.03 |
| | MASK | 23 | 0.89 | 1.09 | 1.00 | 0.01 | 0.05 |
| Adults | | | | | | | |
| BIRT | G20L80 | 24 | 0.97 | 1.31 | 1.09 | 0.02 | 0.09 |
| | G50L50 | 24 | 0.80 | 1.11 | 0.96 | 0.01 | 0.07 |
| | G80L20 | 24 | 0.76 | 1.06 | 0.91 | 0.01 | 0.07 |
| | LONG | 23 | 0.73 | 1.08 | 0.96 | 0.02 | 0.09 |
| | MASK | 24 | 0.76 | 1.17 | 0.97 | 0.02 | 0.09 |
| BIACC | G20L80 | 24 | 0.92 | 1.13 | 1.02 | 0.01 | 0.05 |
| | G50L50 | 24 | 0.93 | 1.05 | 0.99 | 0.01 | 0.03 |
| | G80L20 | 24 | 0.62 | 1.07 | 0.97 | 0.02 | 0.08 |
| | LONG | 23 | 0.95 | 1.05 | 1.00 | 0.01 | 0.03 |
| | MASK | 24 | 0.72 | 1.11 | 1.01 | 0.01 | 0.07 |

Table G.13

*BIRT and BIACC for TD participants with lower and higher AQ scores*

| | Block | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|
| lower AQ | | | | | | | |
| BIRT | G20L80 | 22 | 0.69 | 1.21 | 1.05 | 0.02 | 0.11 |
| | G50L50 | 22 | 0.71 | 1.13 | 0.97 | 0.02 | 0.11 |
| | G80L20 | 22 | 0.55 | 1.10 | 0.86 | 0.03 | 0.12 |
| | LONG | 15 | 0.88 | 1.10 | 1.00 | 0.02 | 0.07 |
| | MASK | 22 | 0.49 | 1.17 | 0.96 | 0.03 | 0.14 |
| BIACC | G20L80 | 22 | 0.91 | 1.23 | 1.03 | 0.02 | 0.07 |
| | G50L50 | 22 | 0.84 | 1.09 | 0.99 | 0.01 | 0.05 |
| | G80L20 | 22 | 0.77 | 1.07 | 0.95 | 0.02 | 0.07 |
| | LONG | 15 | 0.92 | 1.05 | 0.99 | 0.01 | 0.03 |
| | MASK | 22 | 0.65 | 1.30 | 1.01 | 0.02 | 0.11 |
| higher AQ | | | | | | | |
| BIRT | G20L80 | 21 | 0.84 | 1.33 | 1.11 | 0.03 | 0.15 |
| | G50L50 | 22 | 0.71 | 1.15 | 0.92 | 0.02 | 0.11 |
| | G80L20 | 22 | 0.69 | 1.06 | 0.86 | 0.02 | 0.09 |
| | LONG | 16 | 0.80 | 1.03 | 0.95 | 0.02 | 0.07 |
| | MASK | 22 | 0.72 | 1.18 | 0.94 | 0.02 | 0.11 |
| BIACC | G20L80 | 21 | 0.89 | 1.27 | 1.04 | 0.02 | 0.08 |
| | G50L50 | 22 | 0.84 | 1.09 | 0.98 | 0.01 | 0.06 |
| | G80L20 | 22 | 0.84 | 1.09 | 0.98 | 0.01 | 0.07 |
| | LONG | 16 | 0.97 | 1.06 | 1.01 | 0.01 | 0.03 |
| | MASK | 22 | 0.58 | 1.06 | 0.97 | 0.02 | 0.10 |

Table G.14

*BIRT and BIACC for TD participants (younger and older) with lower and higher AQ scores*

| AQ-Group | | | Block | N | Min | Max | M | SE |
|---|---|---|---|---|---|---|---|---|
| lower AQ | younger | | | | | | | |
| | BIRT | G20L80 | 7 | 0.69 | 1.16 | 1.00 | 0.06 | 0.21 |
| | | G50L50 | 7 | 0.71 | 1.06 | 0.91 | 0.06 | 0.17 |
| | | G80L20 | 7 | 0.55 | 1.10 | 0.81 | 0.07 | 0.25 |
| | | LONG | 4 | 0.93 | 1.08 | 1.01 | 0.03 | 0.00 |
| | | MASK | 7 | 0.49 | 1.14 | 0.92 | 0.08 | 0.25 |
| | BIACC | G20L80 | 7 | 0.95 | 1.14 | 1.04 | 0.02 | 0.04 |
| | | G50L50 | 7 | 0.84 | 1.03 | 0.95 | 0.02 | 0.07 |
| | | G80L20 | 7 | 0.77 | 1.02 | 0.95 | 0.03 | 0.12 |
| | | LONG | 4 | 0.92 | 1.03 | 0.99 | 0.02 | 0.00 |
| | | MASK | 7 | 0.65 | 1.30 | 0.98 | 0.07 | 0.27 |
| | older | | | | | | | |
| | BIRT | G20L80 | 15 | 0.97 | 1.21 | 1.08 | 0.02 | 0.07 |
| | | G50L50 | 15 | 0.86 | 1.13 | 0.99 | 0.02 | 0.07 |
| | | G80L20 | 15 | 0.76 | 1.06 | 0.88 | 0.02 | 0.09 |
| | | LONG | 11 | 0.88 | 1.10 | 1.00 | 0.02 | 0.08 |
| | | MASK | 15 | 0.83 | 1.17 | 0.98 | 0.02 | 0.09 |
| | BIACC | G20L80 | 15 | 0.91 | 1.23 | 1.03 | 0.02 | 0.09 |
| | | G50L50 | 15 | 0.93 | 1.09 | 1.00 | 0.01 | 0.04 |
| | | G80L20 | 15 | 0.80 | 1.07 | 0.95 | 0.02 | 0.07 |
| | | LONG | 11 | 0.92 | 1.05 | 1.00 | 0.01 | 0.03 |
| | | MASK | 15 | 0.95 | 1.09 | 1.03 | 0.01 | 0.04 |
| higher AQ | younger | | | | | | | |
| | BIRT | G20L80 | 6 | 0.84 | 1.32 | 1.08 | 0.08 | 0.13 |
| | | G50L50 | 7 | 0.71 | 1.15 | 0.94 | 0.06 | 0.15 |
| | | G80L20 | 7 | 0.69 | 0.93 | 0.82 | 0.03 | 0.10 |
| | | LONG | 4 | 0.90 | 1.03 | 0.97 | 0.03 | 0.00 |
| | | MASK | 7 | 0.78 | 1.18 | 0.91 | 0.05 | 0.08 |
| | BIACC | G20L80 | 6 | 0.89 | 1.27 | 1.07 | 0.05 | 0.13 |
| | | G50L50 | 7 | 0.84 | 1.09 | 0.98 | 0.04 | 0.11 |
| | | G80L20 | 7 | 0.84 | 1.09 | 0.95 | 0.03 | 0.11 |
| | | LONG | 4 | 0.97 | 1.06 | 1.01 | 0.02 | 0.04 |
| | | MASK | 7 | 0.58 | 1.06 | 0.92 | 0.07 | 0.04 |
| | older | | | | | | | |
| | BIRT | G20L80 | 15 | 0.93 | 1.33 | 1.12 | 0.03 | 0.10 |
| | | G50L50 | 15 | 0.76 | 1.09 | 0.91 | 0.02 | 0.11 |
| | | G80L20 | 15 | 0.76 | 1.06 | 0.88 | 0.02 | 0.10 |
| | | LONG | 12 | 0.80 | 1.01 | 0.94 | 0.02 | 0.07 |
| | | MASK | 15 | 0.72 | 1.13 | 0.95 | 0.03 | 0.09 |
| | BIACC | G20L80 | 15 | 0.97 | 1.14 | 1.03 | 0.01 | 0.06 |
| | | G50L50 | 15 | 0.92 | 1.05 | 0.99 | 0.01 | 0.03 |
| | | G80L20 | 15 | 0.84 | 1.07 | 0.99 | 0.01 | 0.03 |
| | | LONG | 12 | 0.98 | 1.05 | 1.01 | 0.01 | 0.03 |
| | | MASK | 15 | 0.90 | 1.03 | 0.99 | 0.01 | 0.03 |

## G.1.2. ASD participants

### G.1.2.1. RT and accuracy in SHORT, LONG, MASK and contingencies

Table G.15

*RT data for ASD participants (overall and split into age groups) in SHORT, LONG, MASK and contingencies*

| Block | Contingency | Level | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| All ages | | | | | | | | |
| SHORT | 20% | global | 48 | 388 | 1245 | 721 | 25 | 170 |
| | | local | 48 | 459 | 1739 | 777 | 32 | 223 |
| | | total | 48 | 428 | 1414 | 748 | 25 | 176 |
| | 50% | global | 48 | 340 | 1392 | 734 | 30 | 209 |
| | | local | 48 | 351 | 1358 | 783 | 32 | 219 |
| | | total | 48 | 346 | 1375 | 758 | 30 | 210 |
| | 80% | global | 48 | 325 | 1036 | 660 | 21 | 149 |
| | | local | 48 | 415 | 1105 | 687 | 20 | 136 |
| | | total | 48 | 416 | 1053 | 674 | 19 | 132 |
| LONG | | global | 50 | 498 | 1371 | 812 | 26 | 185 |
| | | local | 50 | 546 | 1566 | 890 | 30 | 216 |
| MASK | | global | 46 | 342 | 1279 | 752 | 28 | 188 |
| | | local | 46 | 431 | 1365 | 771 | 28 | 189 |
| Children | | | | | | | | |
| SHORT | 20% | global | 11 | 388 | 1245 | 830 | 81 | 269 |
| | | local | 11 | 469 | 1739 | 907 | 96 | 318 |
| | | total | 11 | 428 | 1414 | 867 | 81 | 268 |
| | 50% | global | 11 | 340 | 1240 | 872 | 79 | 263 |
| | | local | 11 | 351 | 1277 | 926 | 83 | 274 |
| | | total | 11 | 346 | 1259 | 899 | 79 | 261 |
| | 80% | global | 11 | 325 | 1001 | 774 | 63 | 210 |
| | | local | 11 | 529 | 1105 | 770 | 56 | 186 |
| | | total | 11 | 427 | 1053 | 774 | 56 | 184 |
| LONG | | global | 12 | 732 | 1371 | 1021 | 59 | 206 |
| | | local | 12 | 778 | 1566 | 1080 | 77 | 268 |
| MASK | | global | 9 | 342 | 1279 | 928 | 97 | 290 |
| | | local | 9 | 453 | 1365 | 967 | 89 | 268 |
| Adolescents | | | | | | | | |
| SHORT | 20% | global | 18 | 441 | 896 | 689 | 28 | 120 |
| | | local | 18 | 459 | 1439 | 752 | 52 | 220 |
| | | total | 18 | 451 | 1088 | 721 | 33 | 139 |
| | 50% | global | 18 | 426 | 1392 | 703 | 52 | 221 |
| | | local | 18 | 409 | 1358 | 727 | 51 | 215 |
| | | total | 18 | 417 | 1375 | 715 | 51 | 216 |
| | 80% | global | 18 | 416 | 1036 | 635 | 31 | 132 |
| | | local | 18 | 415 | 879 | 652 | 27 | 114 |
| | | total | 18 | 416 | 922 | 644 | 26 | 110 |
| LONG | | global | 18 | 498 | 1011 | 750 | 32 | 134 |
| | | local | 18 | 546 | 1380 | 838 | 45 | 192 |
| MASK | | global | 18 | 395 | 959 | 715 | 36 | 155 |
| | | local | 18 | 431 | 954 | 718 | 35 | 148 |
| Adults | | | | | | | | |
| SHORT | 20% | global | 19 | 500 | 930 | 688 | 26 | 112 |
| | | local | 19 | 492 | 967 | 724 | 27 | 117 |
| | | total | 19 | 496 | 877 | 706 | 24 | 106 |
| | 50% | global | 19 | 533 | 963 | 683 | 27 | 118 |
| | | local | 19 | 532 | 1009 | 752 | 35 | 152 |
| | | total | 19 | 533 | 983 | 717 | 31 | 133 |
| | 80% | global | 19 | 480 | 767 | 619 | 18 | 79 |
| | | local | 19 | 521 | 984 | 673 | 25 | 107 |
| | | total | 19 | 503 | 834 | 646 | 20 | 86 |
| LONG | | global | 20 | 568 | 1015 | 743 | 23 | 105 |
| | | local | 20 | 584 | 1123 | 822 | 27 | 123 |
| MASK | | global | 19 | 517 | 838 | 703 | 22 | 97 |
| | | local | 19 | 479 | 938 | 728 | 26 | 113 |

Table G.16

*ACC data for ASD participants (overall and split into age groups) in SHORT, LONG, MASK and contingencies*

| Block | Contingency | Level | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| All ages | | | | | | | | |
| SHORT | 20% | global | 67 | 68.8% | 100.0% | 94.1% | 1.0% | 7.8% |
| | | local | 68 | 56.3% | 100.0% | 93.8% | 1.1% | 9.0% |
| | 50% | global | 68 | 82.5% | 100.0% | 96.3% | 0.6% | 4.6% |
| | | local | 68 | 80.0% | 100.0% | 95.3% | 0.6% | 5.3% |
| | 80% | global | 68 | 85.9% | 100.0% | 96.7% | 0.4% | 3.7% |
| | | local | 67 | 70.3% | 100.0% | 96.4% | 0.6% | 5.3% |
| LONG | | global | 47 | 52.5% | 100.0% | 96.6% | 1.1% | 7.7% |
| | | local | 47 | 75.0% | 100.0% | 96.8% | 0.8% | 5.4% |
| MASK | | global | 68 | 70.0% | 100.0% | 94.4% | 0.8% | 6.7% |
| | | local | 68 | 55.0% | 100.0% | 93.1% | 1.3% | 10.8% |
| Children | | | | | | | | |
| SHORT | 20% | global | 20 | 68.8% | 100.0% | 90.3% | 2.4% | 10.6% |
| | | local | 21 | 75.0% | 100.0% | 93.2% | 1.8% | 8.4% |
| | 50% | global | 21 | 82.5% | 100.0% | 94.8% | 1.2% | 5.4% |
| | | local | 21 | 80.0% | 100.0% | 92.5% | 1.5% | 7.0% |
| | 80% | global | 21 | 85.9% | 100.0% | 95.9% | 0.9% | 4.0% |
| | | local | 20 | 70.3% | 100.0% | 93.5% | 1.8% | 7.9% |
| LONG | | global | 12 | 52.5% | 100.0% | 92.1% | 4.0% | 13.9% |
| | | local | 12 | 75.0% | 100.0% | 93.1% | 2.4% | 8.3% |
| MASK | | global | 21 | 70.0% | 100.0% | 91.4% | 2.0% | 9.3% |
| | | local | 21 | 55.0% | 100.0% | 86.2% | 3.1% | 14.4% |
| Adolescents | | | | | | | | |
| SHORT | 20% | global | 23 | 75.0% | 100.0% | 95.7% | 1.3% | 6.4% |
| | | local | 23 | 68.8% | 100.0% | 93.2% | 1.9% | 9.2% |
| | 50% | global | 23 | 85.0% | 100.0% | 96.6% | 1.0% | 4.6% |
| | | local | 23 | 85.0% | 100.0% | 96.3% | 0.8% | 3.9% |
| | 80% | global | 23 | 85.9% | 100.0% | 96.9% | 0.8% | 3.6% |
| | | local | 23 | 90.6% | 100.0% | 97.5% | 0.6% | 2.8% |
| LONG | | global | 12 | 92.5% | 100.0% | 98.3% | 0.8% | 2.7% |
| | | local | 12 | 85.0% | 100.0% | 98.1% | 1.3% | 4.4% |
| MASK | | global | 23 | 80.0% | 100.0% | 95.8% | 1.2% | 5.8% |
| | | local | 23 | 75.0% | 100.0% | 95.2% | 1.3% | 6.4% |
| Adults | | | | | | | | |
| SHORT | 20% | global | 24 | 87.5% | 100.0% | 95.9% | 1.0% | 5.1% |
| | | local | 24 | 56.3% | 100.0% | 94.8% | 1.9% | 9.5% |
| | 50% | global | 24 | 85.0% | 100.0% | 97.4% | 0.7% | 3.5% |
| | | local | 24 | 85.0% | 100.0% | 96.8% | 0.8% | 3.8% |
| | 80% | global | 24 | 85.9% | 100.0% | 97.2% | 0.7% | 3.5% |
| | | local | 24 | 87.5% | 100.0% | 97.7% | 0.7% | 3.3% |
| LONG | | global | 23 | 87.5% | 100.0% | 98.0% | 0.6% | 3.0% |
| | | local | 23 | 87.5% | 100.0% | 98.0% | 0.6% | 2.8% |
| MASK | | global | 24 | 87.5% | 100.0% | 95.8% | 0.7% | 3.7% |
| | | local | 24 | 65.0% | 100.0% | 97.0% | 1.6% | 7.8% |

### G.1.2.2. RT and accuracy for different priming conditions in SHORT, LONG, MASK and contingencies

Table G.17

*RT data for ASD participants (over all age groups) for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 49 | 556 | 1604 | 902 | 32 | 222 |
| | | level-priming | 49 | 529 | 1360 | 787 | 24 | 166 |
| | | identity-priming | 49 | 453 | 1611 | 767 | 31 | 219 |
| | local | switch | 49 | 598 | 1752 | 941 | 34 | 238 |
| | | level-priming | 49 | 525 | 1614 | 901 | 33 | 229 |
| | | identity-priming | 49 | 499 | 1611 | 810 | 29 | 205 |
| | total | switch | 48 | 587 | 1542 | 917 | 32 | 220 |
| | | level-priming | 48 | 528 | 1379 | 845 | 28 | 192 |
| | | identity-priming | 48 | 476 | 1580 | 789 | 30 | 208 |
| | | nonswitch | 48 | 502 | 1479 | 817 | 28 | 191 |
| | global | PESC | 49 | -154 | 683 | 125 | 20 | 139 |
| | local | PESC | 49 | -99 | 473 | 86 | 17 | 118 |
| SHORT | global | switch | 48 | 365 | 1549 | 798 | 37 | 255 |
| | | level-priming | 48 | 256 | 1184 | 708 | 28 | 193 |
| | | identity-priming | 48 | 359 | 1406 | 698 | 31 | 213 |
| | local | switch | 48 | 358 | 1429 | 820 | 35 | 245 |
| | | level-priming | 48 | 342 | 1362 | 772 | 29 | 200 |
| | | identity-priming | 48 | 367 | 1522 | 755 | 35 | 241 |
| | total | switch | 47 | 362 | 1459 | 808 | 36 | 245 |
| | | level-priming | 47 | 299 | 1273 | 740 | 28 | 191 |
| | | identity-priming | 47 | 363 | 1461 | 726 | 32 | 222 |
| | | nonswitch | 47 | 331 | 1328 | 733 | 29 | 198 |
| | global | PESC | 48 | -117 | 369 | 95 | 15 | 101 |
| | local | PESC | 48 | -299 | 409 | 56 | 16 | 113 |
| MASK | global | switch | 46 | 413 | 1324 | 813 | 30 | 204 |
| | | level-priming | 46 | 244 | 1181 | 727 | 26 | 173 |
| | | identity-priming | 46 | 221 | 1449 | 715 | 30 | 203 |
| | local | switch | 46 | 391 | 1476 | 834 | 35 | 235 |
| | | level-priming | 46 | 373 | 1312 | 761 | 30 | 202 |
| | | identity-priming | 46 | 309 | 1535 | 756 | 31 | 212 |
| | total | switch | 45 | 402 | 1323 | 820 | 32 | 213 |
| | | level-priming | 45 | 337 | 1247 | 742 | 27 | 180 |
| | | identity-priming | 45 | 265 | 1373 | 735 | 29 | 196 |
| | global | PESC | 46 | -53 | 479 | 92 | 16 | 107 |
| | local | PESC | 46 | -371 | 484 | 75 | 21 | 144 |
| G20L80 | global | switch | 48 | 293 | 1403 | 781 | 31 | 216 |
| | | level-priming | 43 | 411 | 1316 | 703 | 27 | 174 |
| | | identity-priming | 45 | 387 | 1134 | 682 | 24 | 163 |
| | local | switch | 48 | 467 | 1181 | 745 | 22 | 152 |
| | | level-priming | 48 | 413 | 1105 | 686 | 22 | 149 |
| | | identity-priming | 48 | 414 | 1213 | 682 | 20 | 141 |
| G80L20 | global | switch | 48 | 434 | 1197 | 724 | 24 | 166 |
| | | level-priming | 48 | 394 | 987 | 656 | 19 | 134 |
| | | identity-priming | 48 | 275 | 1111 | 654 | 24 | 165 |
| | local | switch | 48 | 445 | 2275 | 872 | 43 | 294 |
| | | level-priming | 48 | 461 | 1703 | 733 | 30 | 207 |
| | | identity-priming | 42 | 428 | 1739 | 752 | 42 | 275 |
| 80% contingency | total | switch | 48 | 450 | 1088 | 734 | 20 | 136 |
| | | level-priming | 48 | 403 | 1046 | 671 | 18 | 127 |
| | | identity-priming | 48 | 413 | 1118 | 668 | 20 | 142 |

Table G.18

*RT data for ASD children for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 12 | 727 | 1604 | 1127 | 73 | 253 |
| | | level-priming | 12 | 733 | 1360 | 968 | 54 | 186 |
| | | identity-priming | 12 | 602 | 1611 | 979 | 93 | 322 |
| | local | switch | 12 | 744 | 1752 | 1157 | 90 | 313 |
| | | level-priming | 12 | 772 | 1614 | 1091 | 80 | 277 |
| | | identity-priming | 12 | 719 | 1611 | 1014 | 80 | 276 |
| | total | switch | 12 | 778 | 1542 | 1142 | 78 | 269 |
| | | level-priming | 12 | 805 | 1379 | 1029 | 62 | 216 |
| | | identity-priming | 12 | 660 | 1580 | 996 | 84 | 292 |
| | | nonswitch | 12 | 765 | 1479 | 1013 | 71 | 246 |
| | global | PESC | 12 | -154 | 683 | 154 | 65 | 225 |
| | local | PESC | 12 | -99 | 473 | 105 | 54 | 186 |
| SHORT | global | switch | 11 | 365 | 1397 | 955 | 90 | 299 |
| | | level-priming | 11 | 256 | 1178 | 809 | 80 | 266 |
| | | identity-priming | 11 | 359 | 1399 | 846 | 85 | 283 |
| | local | switch | 11 | 358 | 1429 | 990 | 94 | 310 |
| | | level-priming | 11 | 342 | 1201 | 870 | 72 | 238 |
| | | identity-priming | 11 | 367 | 1522 | 904 | 91 | 303 |
| | total | switch | 11 | 362 | 1346 | 973 | 87 | 290 |
| | | level-priming | 11 | 299 | 1143 | 840 | 75 | 247 |
| | | identity-priming | 11 | 363 | 1461 | 875 | 86 | 284 |
| | | nonswitch | 11 | 331 | 1193 | 857 | 75 | 248 |
| | global | PESC | 11 | -117 | 290 | 127 | 37 | 124 |
| | local | PESC | 11 | -75 | 409 | 103 | 49 | 163 |
| MASK | global | switch | 9 | 531 | 1324 | 1007 | 88 | 263 |
| | | level-priming | 9 | 533 | 1181 | 878 | 67 | 201 |
| | | identity-priming | 9 | 221 | 1449 | 881 | 118 | 353 |
| | local | switch | 9 | 612 | 1476 | 1069 | 107 | 320 |
| | | level-priming | 9 | 373 | 1312 | 971 | 104 | 311 |
| | | identity-priming | 9 | 309 | 1535 | 967 | 115 | 344 |
| | total | switch | 9 | 572 | 1323 | 1038 | 93 | 279 |
| | | level-priming | 9 | 453 | 1247 | 925 | 82 | 247 |
| | | identity-priming | 9 | 265 | 1373 | 924 | 108 | 323 |
| | global | PESC | 9 | -53 | 418 | 127 | 53 | 159 |
| | local | PESC | 9 | -371 | 484 | 100 | 93 | 278 |
| G20L80 | global | switch | 11 | 293 | 1403 | 918 | 103 | 341 |
| | | level-priming | 9 | 432 | 1316 | 803 | 83 | 249 |
| | | identity-priming | 11 | 469 | 1042 | 758 | 62 | 205 |
| | local | switch | 11 | 529 | 979 | 799 | 47 | 157 |
| | | level-priming | 11 | 446 | 1105 | 751 | 64 | 212 |
| | | identity-priming | 11 | 550 | 1213 | 786 | 61 | 202 |
| G80L20 | global | switch | 11 | 455 | 1197 | 831 | 64 | 211 |
| | | level-priming | 11 | 449 | 987 | 773 | 51 | 170 |
| | | identity-priming | 11 | 275 | 1111 | 774 | 73 | 242 |
| | local | switch | 11 | 445 | 2275 | 1018 | 138 | 459 |
| | | level-priming | 11 | 461 | 1703 | 871 | 97 | 320 |
| | | identity-priming | 9 | 477 | 1739 | 937 | 126 | 377 |
| 80% contingency | total | switch | 11 | 492 | 1088 | 815 | 51 | 169 |
| | | level-priming | 11 | 474 | 1046 | 762 | 53 | 176 |
| | | identity-priming | 11 | 413 | 1118 | 780 | 60 | 200 |

Table G.19

*RT data for ASD adolescents for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 17 | 556 | 1199 | 838 | 44 | 182 |
| | | level-priming | 17 | 529 | 1023 | 721 | 32 | 132 |
| | | identity-priming | 17 | 453 | 921 | 713 | 33 | 134 |
| | local | switch | 17 | 598 | 1159 | 869 | 41 | 170 |
| | | level-priming | 17 | 525 | 1350 | 838 | 46 | 191 |
| | | identity-priming | 17 | 499 | 1113 | 750 | 36 | 148 |
| | total | switch | 16 | 587 | 1134 | 834 | 39 | 154 |
| | | level-priming | 16 | 528 | 1187 | 779 | 40 | 160 |
| | | identity-priming | 16 | 476 | 1013 | 730 | 34 | 137 |
| | | nonswitch | 16 | 502 | 1005 | 754 | 34 | 138 |
| | global | PESC | 17 | -20 | 459 | 121 | 29 | 119 |
| | local | PESC | 17 | -74 | 318 | 75 | 21 | 85 |
| SHORT | global | switch | 18 | 447 | 1549 | 762 | 62 | 263 |
| | | level-priming | 18 | 425 | 1184 | 680 | 43 | 182 |
| | | identity-priming | 18 | 421 | 1406 | 676 | 53 | 223 |
| | local | switch | 18 | 425 | 1369 | 758 | 55 | 234 |
| | | level-priming | 18 | 423 | 1362 | 740 | 46 | 196 |
| | | identity-priming | 18 | 396 | 1358 | 722 | 57 | 243 |
| | total | switch | 17 | 436 | 1459 | 756 | 61 | 253 |
| | | level-priming | 17 | 424 | 1273 | 707 | 45 | 187 |
| | | identity-priming | 17 | 408 | 1382 | 694 | 57 | 234 |
| | | nonswitch | 17 | 416 | 1328 | 701 | 50 | 207 |
| | global | PESC | 18 | -65 | 322 | 84 | 22 | 92 |
| | local | PESC | 18 | -299 | 213 | 27 | 26 | 112 |
| MASK | global | switch | 18 | 413 | 1141 | 785 | 47 | 199 |
| | | level-priming | 18 | 244 | 1005 | 680 | 42 | 176 |
| | | identity-priming | 18 | 441 | 1034 | 690 | 36 | 153 |
| | local | switch | 18 | 391 | 1072 | 775 | 46 | 195 |
| | | level-priming | 18 | 431 | 1016 | 695 | 32 | 137 |
| | | identity-priming | 18 | 459 | 952 | 707 | 33 | 138 |
| | total | switch | 17 | 402 | 1012 | 769 | 45 | 187 |
| | | level-priming | 17 | 337 | 898 | 678 | 35 | 145 |
| | | identity-priming | 17 | 450 | 993 | 693 | 33 | 137 |
| | global | PESC | 18 | 19 | 479 | 100 | 25 | 106 |
| | local | PESC | 18 | -72 | 246 | 74 | 22 | 95 |
| G20L80 | global | switch | 18 | 413 | 1001 | 755 | 42 | 177 |
| | | level-priming | 17 | 411 | 1069 | 700 | 39 | 160 |
| | | identity-priming | 18 | 387 | 1134 | 691 | 40 | 170 |
| | local | switch | 18 | 467 | 1181 | 708 | 38 | 160 |
| | | level-priming | 18 | 413 | 895 | 652 | 27 | 116 |
| | | identity-priming | 18 | 414 | 853 | 652 | 26 | 112 |
| G80L20 | global | switch | 18 | 434 | 1191 | 709 | 40 | 169 |
| | | level-priming | 18 | 394 | 957 | 625 | 29 | 121 |
| | | identity-priming | 18 | 431 | 1068 | 637 | 34 | 145 |
| | local | switch | 18 | 459 | 1434 | 864 | 64 | 272 |
| | | level-priming | 18 | 482 | 1043 | 702 | 37 | 157 |
| | | identity-priming | 17 | 428 | 1537 | 712 | 61 | 252 |
| 80% contingency | total | switch | 18 | 450 | 991 | 708 | 30 | 129 |
| | | level-priming | 18 | 403 | 868 | 639 | 24 | 104 |
| | | identity-priming | 18 | 423 | 940 | 644 | 28 | 119 |

Table G.20

*RT data for ASD adults for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 20 | 601 | 1065 | 821 | 29 | 130 |
| | | level-priming | 20 | 552 | 879 | 734 | 20 | 89 |
| | | identity-priming | 20 | 554 | 886 | 686 | 20 | 91 |
| | local | switch | 20 | 624 | 1296 | 873 | 34 | 150 |
| | | level-priming | 20 | 543 | 1147 | 841 | 37 | 164 |
| | | identity-priming | 20 | 567 | 857 | 738 | 21 | 92 |
| | total | switch | 20 | 612 | 1112 | 847 | 29 | 128 |
| | | level-priming | 20 | 572 | 1013 | 788 | 27 | 122 |
| | | identity-priming | 20 | 560 | 836 | 712 | 17 | 77 |
| | | nonswitch | 20 | 566 | 894 | 750 | 20 | 90 |
| | global | PESC | 20 | -20 | 336 | 112 | 19 | 85 |
| | local | PESC | 20 | -58 | 316 | 83 | 20 | 92 |
| SHORT | global | switch | 19 | 534 | 1285 | 740 | 43 | 186 |
| | | level-priming | 19 | 525 | 1071 | 676 | 31 | 136 |
| | | identity-priming | 19 | 506 | 838 | 634 | 21 | 90 |
| | local | switch | 19 | 486 | 1102 | 780 | 38 | 168 |
| | | level-priming | 19 | 494 | 1151 | 746 | 39 | 172 |
| | | identity-priming | 19 | 552 | 1246 | 700 | 38 | 167 |
| | total | switch | 19 | 514 | 1163 | 760 | 39 | 169 |
| | | level-priming | 19 | 514 | 1004 | 711 | 33 | 142 |
| | | identity-priming | 19 | 540 | 1002 | 667 | 27 | 119 |
| | | nonswitch | 19 | 527 | 971 | 689 | 29 | 126 |
| | global | PESC | 19 | -5 | 369 | 85 | 22 | 96 |
| | local | PESC | 19 | -97 | 193 | 57 | 15 | 67 |
| MASK | global | switch | 19 | 586 | 960 | 747 | 25 | 108 |
| | | level-priming | 19 | 481 | 945 | 700 | 26 | 114 |
| | | identity-priming | 19 | 547 | 842 | 661 | 21 | 90 |
| | local | switch | 19 | 503 | 1052 | 778 | 34 | 148 |
| | | level-priming | 19 | 496 | 978 | 725 | 27 | 116 |
| | | identity-priming | 19 | 517 | 1029 | 704 | 28 | 120 |
| | total | switch | 19 | 545 | 986 | 763 | 28 | 123 |
| | | level-priming | 19 | 488 | 962 | 713 | 25 | 109 |
| | | identity-priming | 19 | 534 | 826 | 683 | 20 | 89 |
| | global | PESC | 19 | -41 | 297 | 67 | 17 | 75 |
| | local | PESC | 19 | -69 | 339 | 63 | 21 | 94 |
| G20L80 | global | switch | 19 | 548 | 941 | 725 | 25 | 110 |
| | | level-priming | 17 | 451 | 936 | 653 | 29 | 121 |
| | | identity-priming | 16 | 484 | 826 | 620 | 23 | 94 |
| | local | switch | 19 | 540 | 1039 | 748 | 32 | 140 |
| | | level-priming | 19 | 519 | 1096 | 681 | 29 | 128 |
| | | identity-priming | 19 | 519 | 848 | 651 | 21 | 92 |
| G80L20 | global | switch | 19 | 500 | 937 | 677 | 24 | 103 |
| | | level-priming | 19 | 480 | 772 | 617 | 18 | 79 |
| | | identity-priming | 19 | 465 | 784 | 602 | 19 | 82 |
| | local | switch | 19 | 592 | 1025 | 795 | 33 | 142 |
| | | level-priming | 19 | 484 | 895 | 683 | 29 | 126 |
| | | identity-priming | 16 | 516 | 1274 | 690 | 48 | 191 |
| 80% contingency | total | switch | 19 | 544 | 922 | 712 | 25 | 109 |
| | | level-priming | 19 | 510 | 878 | 649 | 20 | 89 |
| | | identity-priming | 19 | 493 | 808 | 627 | 19 | 81 |

Table G.21

*ACC data for ASD participants (over all age groups) for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 48 | 66.7% | 100.0% | 95.1% | 1.0% | 6.8% |
| | | level-priming | 48 | 76.9% | 100.0% | 96.8% | 0.8% | 5.8% |
| | | identity-priming | 48 | 80.0% | 100.0% | 99.1% | 0.6% | 3.9% |
| | local | switch | 48 | 76.2% | 100.0% | 95.7% | 0.9% | 6.4% |
| | | level-priming | 48 | 57.1% | 100.0% | 96.4% | 1.2% | 8.1% |
| | | identity-priming | 48 | 81.8% | 100.0% | 98.3% | 0.7% | 4.8% |
| | total | switch | 48 | 74.0% | 100.0% | 95.4% | 0.9% | 6.0% |
| | | level-priming | 48 | 73.6% | 100.0% | 96.6% | 0.8% | 5.3% |
| | | identity-priming | 48 | 86.7% | 100.0% | 98.7% | 0.5% | 3.2% |
| | global | PESC | 48 | -11.9% | 22.7% | 2.8% | 0.9% | 6.3% |
| | local | PESC | 48 | -16.5% | 23.8% | 1.6% | 1.0% | 6.7% |
| SHORT | global | switch | 67 | 77.8% | 100.0% | 93.0% | 0.8% | 6.3% |
| | | level-priming | 67 | 77.8% | 100.0% | 96.3% | 0.8% | 6.4% |
| | | identity-priming | 67 | 72.7% | 100.0% | 96.3% | 0.7% | 6.0% |
| | local | switch | 67 | 44.4% | 100.0% | 91.4% | 1.4% | 11.4% |
| | | level-priming | 67 | 47.8% | 100.0% | 93.2% | 1.2% | 10.2% |
| | | identity-priming | 67 | 40.0% | 100.0% | 94.1% | 1.4% | 11.4% |
| | total | switch | 67 | 68.1% | 100.0% | 92.2% | 0.8% | 6.9% |
| | | level-priming | 67 | 72.0% | 100.0% | 94.8% | 0.7% | 5.7% |
| | | identity-priming | 67 | 65.0% | 100.0% | 95.2% | 0.9% | 7.1% |
| | global | PESC | 68 | -11.0% | 17.2% | 3.1% | 0.8% | 6.3% |
| | local | PESC | 68 | -12.5% | 22.2% | 2.2% | 0.9% | 7.5% |
| MASK | global | switch | 66 | 58.3% | 100.0% | 91.6% | 1.0% | 8.5% |
| | | level-priming | 66 | 33.3% | 100.0% | 94.5% | 1.3% | 10.5% |
| | | identity-priming | 66 | 33.3% | 100.0% | 94.2% | 1.4% | 11.4% |
| | local | switch | 66 | 50.0% | 100.0% | 89.0% | 1.6% | 12.6% |
| | | level-priming | 66 | 50.0% | 100.0% | 92.8% | 1.5% | 11.8% |
| | | identity-priming | 66 | 45.5% | 100.0% | 93.6% | 1.5% | 12.6% |
| | total | switch | 66 | 63.9% | 100.0% | 90.3% | 1.0% | 8.2% |
| | | level-priming | 66 | 66.7% | 100.0% | 93.7% | 1.0% | 8.5% |
| | | identity-priming | 66 | 59.5% | 100.0% | 93.9% | 1.2% | 9.8% |
| | global | PESC | 66 | -32.1% | 34.5% | 2.8% | 1.2% | 10.1% |
| | local | PESC | 66 | -13.7% | 28.9% | 4.2% | 1.1% | 8.9% |
| G20L80 | global | switch | 66 | 50.0% | 100.0% | 91.1% | 1.4% | 11.0% |
| | | level-priming | 53 | 50.0% | 100.0% | 97.2% | 1.5% | 10.6% |
| | | identity-priming | 53 | 50.0% | 100.0% | 98.4% | 1.1% | 8.2% |
| | local | switch | 66 | 20.0% | 100.0% | 93.2% | 1.6% | 13.0% |
| | | level-priming | 66 | 42.9% | 100.0% | 94.9% | 1.1% | 8.9% |
| | | identity-priming | 66 | 55.0% | 100.0% | 96.2% | 0.9% | 7.2% |
| G80L20 | global | switch | 67 | 76.9% | 100.0% | 94.2% | 0.8% | 6.6% |
| | | level-priming | 67 | 77.3% | 100.0% | 95.8% | 0.6% | 5.0% |
| | | identity-priming | 67 | 85.2% | 100.0% | 96.8% | 0.5% | 4.1% |
| | local | switch | 67 | 53.3% | 100.0% | 91.6% | 1.3% | 11.0% |
| | | level-priming | 54 | 50.0% | 100.0% | 96.5% | 1.4% | 10.2% |
| | | identity-priming | 50 | 87.5% | 100.0% | 99.8% | 0.3% | 1.8% |
| 80% contingency | total | switch | 67 | 60.0% | 100.0% | 93.7% | 0.9% | 7.5% |
| | | level-priming | 67 | 71.4% | 100.0% | 95.3% | 0.6% | 5.1% |
| | | identity-priming | 67 | 77.5% | 100.0% | 96.5% | 0.5% | 4.5% |

Table G.22

*ACC data for ASD children for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 13 | 66.7% | 100.0% | 90.8% | 2.7% | 9.7% |
| | | level-priming | 13 | 90.0% | 100.0% | 97.5% | 1.1% | 3.9% |
| | | identity-priming | 13 | 80.0% | 100.0% | 97.2% | 1.9% | 6.9% |
| | local | switch | 13 | 81.3% | 100.0% | 94.4% | 2.1% | 7.6% |
| | | level-priming | 13 | 57.1% | 100.0% | 93.1% | 3.7% | 13.4% |
| | | identity-priming | 13 | 81.8% | 100.0% | 95.9% | 1.9% | 6.9% |
| | total | switch | 13 | 74.0% | 100.0% | 92.6% | 2.2% | 8.1% |
| | | level-priming | 13 | 73.6% | 100.0% | 95.3% | 2.2% | 8.1% |
| | | identity-priming | 13 | 86.7% | 100.0% | 96.5% | 1.4% | 4.9% |
| | global | PESC | 13 | -3.8% | 22.7% | 6.5% | 2.2% | 8.0% |
| | local | PESC | 13 | -16.5% | 11.7% | 0.1% | 2.3% | 8.1% |
| SHORT | global | switch | 21 | 77.8% | 100.0% | 91.5% | 1.3% | 6.0% |
| | | level-priming | 21 | 80.0% | 100.0% | 96.6% | 1.4% | 6.3% |
| | | identity-priming | 21 | 72.7% | 100.0% | 93.6% | 1.7% | 7.9% |
| | local | switch | 21 | 44.4% | 100.0% | 85.2% | 3.4% | 15.7% |
| | | level-priming | 21 | 47.8% | 100.0% | 88.3% | 3.3% | 15.2% |
| | | identity-priming | 21 | 40.0% | 100.0% | 88.0% | 3.7% | 16.7% |
| | total | switch | 21 | 68.1% | 100.0% | 88.3% | 1.9% | 8.8% |
| | | level-priming | 21 | 72.0% | 100.0% | 92.5% | 1.6% | 7.6% |
| | | identity-priming | 21 | 65.0% | 100.0% | 90.8% | 2.1% | 9.7% |
| | global | PESC | 21 | -8.4% | 13.0% | 3.6% | 1.4% | 6.3% |
| | local | PESC | 21 | -12.5% | 22.2% | 3.0% | 2.1% | 9.6% |
| MASK | global | switch | 20 | 58.3% | 100.0% | 88.2% | 2.5% | 11.3% |
| | | level-priming | 20 | 33.3% | 100.0% | 90.2% | 3.5% | 15.4% |
| | | identity-priming | 20 | 50.0% | 100.0% | 91.4% | 2.7% | 12.1% |
| | local | switch | 20 | 50.0% | 100.0% | 81.8% | 3.5% | 15.6% |
| | | level-priming | 20 | 66.7% | 100.0% | 87.4% | 3.1% | 13.9% |
| | | identity-priming | 20 | 45.5% | 100.0% | 85.8% | 4.0% | 18.1% |
| | total | switch | 20 | 63.9% | 97.5% | 85.0% | 2.1% | 9.4% |
| | | level-priming | 20 | 66.7% | 100.0% | 88.8% | 2.1% | 9.5% |
| | | identity-priming | 20 | 60.0% | 100.0% | 88.6% | 2.7% | 12.1% |
| | global | PESC | 20 | -20.8% | 34.5% | 2.6% | 2.6% | 11.7% |
| | local | PESC | 20 | -13.7% | 28.9% | 4.8% | 2.8% | 12.6% |
| G20L80 | global | switch | 20 | 69.2% | 100.0% | 87.8% | 2.6% | 11.7% |
| | | level-priming | 15 | 50.0% | 100.0% | 95.0% | 3.6% | 14.0% |
| | | identity-priming | 13 | 66.7% | 100.0% | 97.4% | 2.6% | 9.2% |
| | local | switch | 20 | 20.0% | 100.0% | 86.7% | 4.6% | 20.4% |
| | | level-priming | 20 | 42.9% | 100.0% | 89.4% | 3.1% | 14.0% |
| | | identity-priming | 20 | 55.0% | 100.0% | 92.9% | 2.5% | 11.0% |
| G80L20 | global | switch | 21 | 76.9% | 100.0% | 90.5% | 1.5% | 6.7% |
| | | level-priming | 21 | 85.0% | 100.0% | 95.8% | 0.9% | 4.0% |
| | | identity-priming | 21 | 85.2% | 100.0% | 94.7% | 1.1% | 4.8% |
| | local | switch | 21 | 69.2% | 100.0% | 90.4% | 2.2% | 10.2% |
| | | level-priming | 18 | 66.7% | 100.0% | 98.1% | 1.9% | 7.9% |
| | | identity-priming | 14 | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% |
| 80% contingency | total | switch | 21 | 60.0% | 100.0% | 88.6% | 2.1% | 9.5% |
| | | level-priming | 21 | 71.4% | 100.0% | 92.7% | 1.5% | 7.1% |
| | | identity-priming | 21 | 77.5% | 100.0% | 93.9% | 1.3% | 6.0% |

Table G.23

*ACC data for ASD adolescents for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 12 | 85.7% | 100.0% | 94.7% | 1.5% | 5.1% |
| | | level-priming | 12 | 76.9% | 100.0% | 96.5% | 2.1% | 7.1% |
| | | identity-priming | 12 | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% |
| | local | switch | 12 | 78.6% | 100.0% | 94.8% | 1.9% | 6.6% |
| | | level-priming | 12 | 84.6% | 100.0% | 96.8% | 1.5% | 5.2% |
| | | identity-priming | 12 | 84.6% | 100.0% | 98.7% | 1.3% | 4.4% |
| | total | switch | 12 | 82.1% | 100.0% | 94.8% | 1.6% | 5.7% |
| | | level-priming | 12 | 84.6% | 100.0% | 96.7% | 1.4% | 4.9% |
| | | identity-priming | 12 | 92.3% | 100.0% | 99.4% | 0.6% | 2.2% |
| | global | PESC | 12 | -5.0% | 14.3% | 3.6% | 1.4% | 5.0% |
| | local | PESC | 12 | -1.1% | 17.6% | 2.9% | 1.5% | 5.2% |
| SHORT | global | switch | 23 | 77.8% | 100.0% | 92.8% | 1.5% | 7.2% |
| | | level-priming | 23 | 77.8% | 100.0% | 95.3% | 1.5% | 7.1% |
| | | identity-priming | 23 | 83.3% | 100.0% | 96.4% | 1.0% | 4.9% |
| | local | switch | 23 | 79.2% | 100.0% | 94.3% | 1.2% | 5.9% |
| | | level-priming | 23 | 83.3% | 100.0% | 95.5% | 1.3% | 6.1% |
| | | identity-priming | 23 | 86.0% | 100.0% | 97.0% | 0.9% | 4.2% |
| | total | switch | 23 | 83.3% | 100.0% | 93.5% | 1.1% | 5.1% |
| | | level-priming | 23 | 88.2% | 100.0% | 95.4% | 0.9% | 4.3% |
| | | identity-priming | 23 | 86.7% | 100.0% | 96.7% | 0.8% | 4.1% |
| | global | PESC | 23 | -11.0% | 17.2% | 3.0% | 1.5% | 7.0% |
| | local | PESC | 23 | -10.0% | 19.0% | 2.0% | 1.5% | 7.1% |
| MASK | global | switch | 23 | 68.8% | 100.0% | 93.6% | 1.6% | 7.7% |
| | | level-priming | 23 | 71.4% | 100.0% | 96.1% | 1.6% | 7.6% |
| | | identity-priming | 23 | 33.3% | 100.0% | 94.3% | 3.0% | 14.5% |
| | local | switch | 23 | 61.9% | 100.0% | 91.7% | 1.8% | 8.8% |
| | | level-priming | 23 | 76.9% | 100.0% | 95.2% | 1.5% | 7.4% |
| | | identity-priming | 23 | 81.8% | 100.0% | 97.6% | 1.1% | 5.4% |
| | total | switch | 23 | 76.2% | 100.0% | 92.6% | 1.2% | 5.9% |
| | | level-priming | 23 | 80.7% | 100.0% | 95.7% | 1.2% | 5.7% |
| | | identity-priming | 23 | 59.5% | 100.0% | 96.0% | 1.9% | 9.1% |
| | global | PESC | 23 | -32.1% | 24.6% | 1.6% | 2.3% | 11.1% |
| | local | PESC | 23 | -6.6% | 26.8% | 4.8% | 1.4% | 6.9% |
| G20L80 | global | switch | 23 | 66.7% | 100.0% | 93.1% | 2.0% | 9.7% |
| | | level-priming | 18 | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% |
| | | identity-priming | 20 | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% |
| | local | switch | 23 | 76.9% | 100.0% | 95.6% | 1.4% | 6.5% |
| | | level-priming | 23 | 87.5% | 100.0% | 96.8% | 0.7% | 3.5% |
| | | identity-priming | 23 | 86.7% | 100.0% | 98.0% | 0.8% | 3.7% |
| G80L20 | global | switch | 23 | 78.6% | 100.0% | 95.1% | 1.4% | 6.5% |
| | | level-priming | 23 | 77.3% | 100.0% | 96.2% | 1.2% | 5.9% |
| | | identity-priming | 23 | 86.4% | 100.0% | 96.9% | 0.8% | 4.0% |
| | local | switch | 23 | 58.3% | 100.0% | 91.7% | 2.4% | 11.5% |
| | | level-priming | 19 | 50.0% | 100.0% | 93.4% | 3.3% | 14.3% |
| | | identity-priming | 16 | 87.5% | 100.0% | 99.2% | 0.8% | 3.1% |
| 80% contingency | total | switch | 23 | 84.3% | 100.0% | 95.3% | 1.1% | 5.2% |
| | | level-priming | 23 | 86.9% | 100.0% | 96.5% | 0.8% | 3.6% |
| | | identity-priming | 23 | 88.3% | 100.0% | 97.4% | 0.7% | 3.3% |

Table G.24

*ACC data for ASD adults for different priming conditions in SHORT, LONG, MASK and contingencies*

| Block | Level | Condition | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|---|
| LONG | global | switch | 23 | 85.7% | 100.0% | 97.8% | 0.8% | 3.9% |
| | | level-priming | 23 | 81.8% | 100.0% | 96.6% | 1.3% | 6.1% |
| | | identity-priming | 23 | 91.7% | 100.0% | 99.6% | 0.4% | 1.7% |
| | local | switch | 23 | 76.2% | 100.0% | 97.0% | 1.1% | 5.4% |
| | | level-priming | 23 | 83.3% | 100.0% | 98.1% | 1.0% | 4.6% |
| | | identity-priming | 23 | 85.7% | 100.0% | 99.4% | 0.6% | 3.0% |
| | total | switch | 23 | 81.0% | 100.0% | 97.4% | 0.8% | 4.1% |
| | | level-priming | 23 | 90.9% | 100.0% | 97.3% | 0.7% | 3.3% |
| | | identity-priming | 23 | 92.9% | 100.0% | 99.5% | 0.4% | 1.7% |
| | global | PESC | 23 | -11.9% | 9.1% | 0.3% | 1.0% | 4.7% |
| | local | PESC | 23 | -8.3% | 23.8% | 1.7% | 1.4% | 6.5% |
| SHORT | global | switch | 23 | 82.4% | 100.0% | 94.6% | 1.1% | 5.5% |
| | | level-priming | 23 | 80.0% | 100.0% | 97.1% | 1.2% | 5.9% |
| | | identity-priming | 23 | 87.5% | 100.0% | 98.6% | 0.8% | 3.9% |
| | local | switch | 23 | 61.5% | 100.0% | 94.1% | 1.8% | 8.9% |
| | | level-priming | 23 | 84.6% | 100.0% | 95.5% | 1.2% | 5.6% |
| | | identity-priming | 23 | 69.2% | 100.0% | 96.8% | 1.7% | 8.0% |
| | total | switch | 23 | 80.8% | 100.0% | 94.3% | 1.1% | 5.2% |
| | | level-priming | 23 | 82.9% | 100.0% | 96.3% | 0.9% | 4.3% |
| | | identity-priming | 23 | 83.0% | 100.0% | 97.7% | 1.0% | 4.9% |
| | global | PESC | 24 | -8.0% | 14.3% | 2.8% | 1.2% | 5.7% |
| | local | PESC | 24 | -8.0% | 16.7% | 1.6% | 1.2% | 5.9% |
| MASK | global | switch | 23 | 81.3% | 100.0% | 92.5% | 1.1% | 5.4% |
| | | level-priming | 23 | 81.8% | 100.0% | 96.7% | 1.3% | 6.1% |
| | | identity-priming | 23 | 76.9% | 100.0% | 96.5% | 1.3% | 6.1% |
| | local | switch | 23 | 60.0% | 100.0% | 92.8% | 2.2% | 10.7% |
| | | level-priming | 23 | 50.0% | 100.0% | 95.2% | 2.6% | 12.3% |
| | | identity-priming | 23 | 70.0% | 100.0% | 96.3% | 1.8% | 8.7% |
| | total | switch | 23 | 74.7% | 100.0% | 92.6% | 1.4% | 6.9% |
| | | level-priming | 23 | 67.3% | 100.0% | 95.9% | 1.8% | 8.4% |
| | | identity-priming | 23 | 76.0% | 100.0% | 96.4% | 1.3% | 6.4% |
| | global | PESC | 23 | -11.5% | 18.8% | 4.1% | 1.6% | 7.5% |
| | local | PESC | 23 | -8.9% | 21.4% | 3.0% | 1.4% | 6.9% |
| G20L80 | global | switch | 23 | 50.0% | 100.0% | 92.1% | 2.4% | 11.4% |
| | | level-priming | 20 | 50.0% | 100.0% | 96.3% | 2.7% | 12.2% |
| | | identity-priming | 20 | 50.0% | 100.0% | 97.5% | 2.5% | 11.2% |
| | local | switch | 23 | 78.6% | 100.0% | 96.5% | 1.3% | 6.4% |
| | | level-priming | 23 | 87.1% | 100.0% | 97.8% | 0.7% | 3.3% |
| | | identity-priming | 23 | 80.0% | 100.0% | 97.3% | 0.9% | 4.4% |
| G80L20 | global | switch | 23 | 84.6% | 100.0% | 96.8% | 1.1% | 5.3% |
| | | level-priming | 23 | 80.0% | 100.0% | 95.4% | 1.0% | 4.9% |
| | | identity-priming | 23 | 93.1% | 100.0% | 98.8% | 0.5% | 2.2% |
| | local | switch | 23 | 53.3% | 100.0% | 92.5% | 2.4% | 11.6% |
| | | level-priming | 17 | 83.3% | 100.0% | 98.0% | 1.3% | 5.5% |
| | | identity-priming | 20 | 100.0% | 100.0% | 100.0% | 0.0% | 0.0% |
| 80% contingency | total | switch | 23 | 82.6% | 100.0% | 96.6% | 1.0% | 4.9% |
| | | level-priming | 23 | 87.8% | 100.0% | 96.6% | 0.7% | 3.1% |
| | | identity-priming | 23 | 88.1% | 100.0% | 98.1% | 0.5% | 2.5% |

### G.1.2.3. BI data for ASD depending on age group and AQ group

Table G.25

*BIRT and BIACC for ASD participants (overall and split into age groups)*

| | Block | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|
| All age groups | | | | | | | |
| BIRT | G20L80 | 48 | 0.73 | 1.48 | 1.05 | 0.02 | 0.14 |
| | G50L50 | 48 | 0.77 | 1.16 | 0.94 | 0.01 | 0.08 |
| | G80L20 | 48 | 0.49 | 1.17 | 0.86 | 0.02 | 0.11 |
| | LONG | 50 | 0.73 | 1.13 | 0.92 | 0.01 | 0.09 |
| | MASK | 46 | 0.76 | 1.15 | 0.98 | 0.01 | 0.08 |
| BIACC | G20L80 | 48 | 0.73 | 1.54 | 1.03 | 0.02 | 0.12 |
| | G50L50 | 48 | 0.83 | 1.09 | 0.99 | 0.01 | 0.05 |
| | G80L20 | 48 | 0.75 | 1.08 | 0.97 | 0.01 | 0.07 |
| | LONG | 50 | 0.90 | 1.20 | 1.01 | 0.01 | 0.06 |
| | MASK | 46 | 0.58 | 1.09 | 0.95 | 0.02 | 0.11 |
| Children | | | | | | | |
| BIRT | G20L80 | 11 | 0.73 | 1.34 | 1.06 | 0.05 | 0.16 |
| | G50L50 | 11 | 0.77 | 1.16 | 0.95 | 0.04 | 0.12 |
| | G80L20 | 11 | 0.49 | 1.17 | 0.88 | 0.06 | 0.18 |
| | LONG | 12 | 0.81 | 1.13 | 0.96 | 0.03 | 0.11 |
| | MASK | 9 | 0.76 | 1.05 | 0.95 | 0.03 | 0.10 |
| BIACC | G20L80 | 11 | 0.89 | 1.54 | 1.09 | 0.06 | 0.21 |
| | G50L50 | 11 | 0.83 | 1.08 | 0.98 | 0.02 | 0.06 |
| | G80L20 | 11 | 0.76 | 1.08 | 0.95 | 0.03 | 0.10 |
| | LONG | 12 | 0.92 | 1.20 | 1.03 | 0.03 | 0.09 |
| | MASK | 9 | 0.70 | 1.09 | 0.92 | 0.04 | 0.11 |
| Adolescents | | | | | | | |
| BIRT | G20L80 | 18 | 0.90 | 1.28 | 1.06 | 0.03 | 0.11 |
| | G50L50 | 18 | 0.84 | 1.12 | 0.97 | 0.02 | 0.08 |
| | G80L20 | 18 | 0.66 | 0.98 | 0.86 | 0.02 | 0.09 |
| | LONG | 18 | 0.73 | 1.05 | 0.91 | 0.02 | 0.08 |
| | MASK | 18 | 0.86 | 1.15 | 0.99 | 0.02 | 0.08 |
| BIACC | G20L80 | 18 | 0.95 | 1.16 | 1.01 | 0.01 | 0.04 |
| | G50L50 | 18 | 0.92 | 1.09 | 1.01 | 0.01 | 0.04 |
| | G80L20 | 18 | 0.75 | 1.05 | 0.96 | 0.02 | 0.07 |
| | LONG | 18 | 0.95 | 1.12 | 1.01 | 0.01 | 0.04 |
| | MASK | 18 | 0.59 | 1.08 | 0.96 | 0.02 | 0.11 |
| Adults | | | | | | | |
| BIRT | G20L80 | 19 | 0.74 | 1.48 | 1.03 | 0.04 | 0.16 |
| | G50L50 | 19 | 0.79 | 1.00 | 0.91 | 0.01 | 0.06 |
| | G80L20 | 19 | 0.75 | 0.99 | 0.86 | 0.02 | 0.07 |
| | LONG | 20 | 0.73 | 1.13 | 0.91 | 0.02 | 0.09 |
| | MASK | 19 | 0.78 | 1.08 | 0.97 | 0.02 | 0.07 |
| BIACC | G20L80 | 19 | 0.73 | 1.14 | 1.01 | 0.02 | 0.09 |
| | G50L50 | 19 | 0.86 | 1.05 | 0.99 | 0.01 | 0.05 |
| | G80L20 | 19 | 0.88 | 1.08 | 0.98 | 0.01 | 0.06 |
| | LONG | 20 | 0.90 | 1.08 | 1.01 | 0.01 | 0.04 |
| | MASK | 19 | 0.58 | 1.08 | 0.96 | 0.03 | 0.12 |

Table G.26

*BIRT and BIACC for ASD participants with lower and higher AQ scores*

| | Block | N | Min | Max | M | SE | SD |
|---|---|---|---|---|---|---|---|
| lower AQ | | | | | | | |
| BIRT | G20L80 | 15 | 0.69 | 1.21 | 1.07 | 0.03 | 0.12 |
| | G50L50 | 15 | 0.71 | 1.13 | 0.94 | 0.03 | 0.12 |
| | G80L20 | 15 | 0.55 | 1.10 | 0.86 | 0.04 | 0.14 |
| | LONG | 8 | 0.88 | 1.08 | 0.99 | 0.02 | 0.07 |
| | MASK | 15 | 0.49 | 1.17 | 0.94 | 0.04 | 0.15 |
| BIACC | G20L80 | 15 | 0.91 | 1.23 | 1.03 | 0.02 | 0.08 |
| | G50L50 | 15 | 0.84 | 1.09 | 0.99 | 0.02 | 0.06 |
| | G80L20 | 15 | 0.77 | 1.02 | 0.94 | 0.02 | 0.08 |
| | LONG | 8 | 0.92 | 1.00 | 0.99 | 0.01 | 0.03 |
| | MASK | 15 | 0.65 | 1.30 | 1.02 | 0.03 | 0.13 |
| higher AQ | | | | | | | |
| BIRT | G20L80 | 12 | 0.95 | 1.27 | 1.12 | 0.03 | 0.10 |
| | G50L50 | 13 | 0.76 | 1.15 | 0.95 | 0.03 | 0.12 |
| | G80L20 | 13 | 0.69 | 1.06 | 0.85 | 0.03 | 0.10 |
| | LONG | 9 | 0.82 | 1.01 | 0.95 | 0.02 | 0.06 |
| | MASK | 13 | 0.78 | 1.13 | 0.92 | 0.03 | 0.09 |
| BIACC | G20L80 | 12 | 0.97 | 1.27 | 1.05 | 0.03 | 0.09 |
| | G50L50 | 13 | 0.84 | 1.09 | 1.00 | 0.02 | 0.06 |
| | G80L20 | 13 | 0.84 | 1.09 | 0.99 | 0.02 | 0.06 |
| | LONG | 9 | 0.98 | 1.06 | 1.01 | 0.01 | 0.03 |
| | MASK | 13 | 0.94 | 1.06 | 1.00 | 0.01 | 0.03 |

Table G.27

*BIRT and BIACC for ASD participants (younger and older) with lower and higher AQ scores*

| AQ-Group | | | Block | N | Min | Max | M | SE |
|---|---|---|---|---|---|---|---|---|
| lower AQ | younger | | | | | | | |
| | BIRT | G20L80 | 4 | 0.91 | 1.16 | 1.04 | 0.06 | 0.21 |
| | | G50L50 | 4 | 0.93 | 1.13 | 1.01 | 0.04 | 0.17 |
| | | G80L20 | 4 | 0.80 | 1.17 | 0.97 | 0.08 | 0.25 |
| | | LONG | 5 | 0.84 | 1.03 | 0.91 | 0.04 | 0.00 |
| | | MASK | 3 | 0.92 | 1.01 | 0.97 | 0.03 | 0.25 |
| | BIACC | G20L80 | 4 | 0.94 | 1.13 | 1.04 | 0.04 | 0.04 |
| | | G50L50 | 4 | 0.95 | 1.08 | 1.00 | 0.03 | 0.07 |
| | | G80L20 | 4 | 0.84 | 1.05 | 0.94 | 0.05 | 0.12 |
| | | LONG | 5 | 0.92 | 1.14 | 1.02 | 0.04 | 0.00 |
| | | MASK | 3 | 0.88 | 1.09 | 0.95 | 0.07 | 0.27 |
| | older | | | | | | | |
| | BIRT | G20L80 | 13 | 0.91 | 1.19 | 1.04 | 0.02 | 0.07 |
| | | G50L50 | 13 | 0.89 | 1.11 | 0.97 | 0.02 | 0.07 |
| | | G80L20 | 13 | 0.72 | 0.98 | 0.86 | 0.02 | 0.09 |
| | | LONG | 13 | 0.73 | 1.05 | 0.91 | 0.02 | 0.08 |
| | | MASK | 13 | 0.86 | 1.12 | 1.00 | 0.02 | 0.09 |
| | BIACC | G20L80 | 13 | 0.97 | 1.16 | 1.02 | 0.02 | 0.09 |
| | | G50L50 | 13 | 0.92 | 1.09 | 1.00 | 0.01 | 0.04 |
| | | G80L20 | 13 | 0.75 | 1.02 | 0.95 | 0.02 | 0.07 |
| | | LONG | 13 | 0.90 | 1.12 | 1.00 | 0.01 | 0.03 |
| | | MASK | 13 | 0.59 | 1.03 | 0.94 | 0.03 | 0.04 |
| higher AQ | younger | | | | | | | |
| | BIRT | G20L80 | 4 | 0.73 | 1.07 | 0.96 | 0.08 | 0.13 |
| | | G50L50 | 4 | 0.77 | 1.16 | 0.92 | 0.09 | 0.15 |
| | | G80L20 | 4 | 0.69 | 1.00 | 0.85 | 0.08 | 0.10 |
| | | LONG | 4 | 0.81 | 1.13 | 1.01 | 0.07 | 0.00 |
| | | MASK | 3 | 0.76 | 1.05 | 0.94 | 0.09 | 0.08 |
| | BIACC | G20L80 | 4 | 0.97 | 1.54 | 1.23 | 0.15 | 0.13 |
| | | G50L50 | 4 | 0.83 | 1.03 | 0.95 | 0.04 | 0.11 |
| | | G80L20 | 4 | 0.98 | 1.08 | 1.02 | 0.02 | 0.11 |
| | | LONG | 4 | 0.95 | 1.20 | 1.06 | 0.06 | 0.04 |
| | | MASK | 3 | 0.70 | 0.95 | 0.87 | 0.08 | 0.04 |
| | older | | | | | | | |
| | BIRT | G20L80 | 13 | 0.74 | 1.23 | 1.04 | 0.04 | 0.10 |
| | | G50L50 | 13 | 0.81 | 1.12 | 0.94 | 0.02 | 0.11 |
| | | G80L20 | 13 | 0.66 | 0.98 | 0.85 | 0.02 | 0.10 |
| | | LONG | 13 | 0.73 | 1.13 | 0.91 | 0.03 | 0.07 |
| | | MASK | 13 | 0.92 | 1.15 | 0.99 | 0.02 | 0.09 |
| | BIACC | G20L80 | 13 | 0.73 | 1.13 | 0.99 | 0.03 | 0.06 |
| | | G50L50 | 13 | 0.98 | 1.05 | 1.01 | 0.01 | 0.03 |
| | | G80L20 | 13 | 0.88 | 1.08 | 0.98 | 0.02 | 0.03 |
| | | LONG | 13 | 0.95 | 1.08 | 1.02 | 0.01 | 0.03 |
| | | MASK | 13 | 0.58 | 1.08 | 0.95 | 0.04 | 0.03 |

## G.2. ANOVA results

### G.2.1. Contingency Manipulation

Table G.28

*Contingency Manipulation - RT & ACC: Results of the 2x3x2 (and 2x3x2x2) repeated measures ANOVAs with the factors level, contingency, age group (and sample group)*

| | | DV RT | | | DV ACC | | |
|---|---|---|---|---|---|---|---|
| | df | F | p | η2 | F | p | η2 |
| TD | | | | | | | |
| Level | 1 | 27.375 | <.001 | .300 | 1.994 | .163 | .030 |
| Level x Age Group | 2 | 2.501 | .090 | .073 | 0.078 | .925 | .002 |
| Contingency | 2 | 59.406 | <.001 | .481 | 11.884 | <.001 | .157 |
| Contingency x Age Group | 4 | 1.443 | .224 | .043 | 0.153 | .961 | .005 |
| Level x Contingency | 2 | 1.155 | .318 | .018 | 0.354 | .703 | .005 |
| Level x Contingency x Age Group | 4 | 1.132 | .344 | .034 | 3.355 | .012 | .095 |
| Age Group | 2 | 31.342 | <.001 | .495 | 3.018 | .056 | .086 |
| ASD | | | | | | | |
| Level | 1 | 27.033 | <.001 | .375 | 1.726 | .196 | .037 |
| Level x Age Group | 2 | 0.681 | .511 | .029 | 0.015 | .986 | .001 |
| Contingency | 2 | 22.569 | <.001 | .334 | 15.287 | <.001 | .254 |
| Contingency x Age Group | 4 | 0.401 | .808 | .017 | 3.972 | .005 | .150 |
| Level x Contingency | 2 | 0.207 | .813 | .005 | 5.982 | .004 | .117 |
| Level x Contingency x Age Group | 4 | 0.404 | .805 | .018 | 1.739 | .148 | .072 |
| Age Group | 2 | 2.193 | .123 | .089 | 6.843 | .003 | .233 |
| ASD & AmTD | | | | | | | |
| Level | 1 | 41.769 | <.001 | .327 | 1.875 | .174 | .021 |
| Level x Age Group | 2 | 0.395 | .675 | .009 | 0.090 | .914 | .002 |
| Level x Sample | 1 | 0.251 | .618 | .003 | 0.383 | .538 | .004 |
| Level x Age Group x Sample | 2 | 1.962 | .147 | .044 | 0.032 | .969 | .001 |
| Contingency | 2 | 65.264 | <.001 | .431 | 20.790 | <.001 | .195 |
| Contingency x Age Group | 4 | 0.724 | .577 | .017 | 1.748 | .142 | .039 |
| Contingency x Sample | 2 | 0.674 | .511 | .008 | 0.812 | .446 | .009 |
| Contingency x Age Group x Sample | 4 | 0.248 | .911 | .006 | 1.998 | .097 | .044 |
| Level x Contingency | 2 | 0.537 | .585 | .006 | 2.973 | .054 | .033 |
| Level x Contingency x Age Group | 4 | 0.603 | .661 | .014 | 3.328 | .012 | .072 |
| Level x Contingency x Sample | 2 | 0.269 | .765 | .003 | 4.159 | .017 | .046 |
| Level x Contingency x Age Group x Sample | 4 | 0.123 | .974 | .003 | 0.179 | .949 | .004 |
| Age Group | 2 | 11.679 | <.001 | .214 | 8.032 | .001 | .157 |
| Sample | 1 | 0.072 | .790 | .001 | 2.500 | .118 | .028 |
| Age Group x Sample | 1 | 1.656 | .197 | .037 | 2.369 | .100 | .052 |

Table G.29

*Contingency Manipulation - BI: Results of 3x2 (and 3x2x2) repeated measures ANOVAs with the factors Block, age group (and sample group)*

| | | DV BIRT | | | DV BIACC | | |
|---|---|---|---|---|---|---|---|
| | df | F | p | $\eta^2$ | F | p | $\eta^2$ |
| TD | | | | | | | |
| Block | 2 | 82.749 | <.001 | .564 | 14.402 | <.001 | .184 |
| Block x Age Group | 4 | 0.705 | .590 | .022 | 0.809 | .522 | .025 |
| Age Group | 2 | 2.390 | .100 | .069 | 0.028 | .972 | .001 |
| ASD | | | | | | | |
| Block | 2 | 32.016 | <.001 | .416 | 8.896 | <.001 | .165 |
| Block x Age Group | 4 | 0.251 | .908 | .011 | 2.121 | .085 | .086 |
| Age Group | 2 | 0.802 | .455 | .034 | 0.192 | .826 | .008 |
| ASD & AmTD | | | | | | | |
| Block | 2 | 94.034 | <.001 | .522 | 17.172 | <.001 | .166 |
| Block x Age Group | 4 | 0.707 | .588 | .016 | 2.262 | .064 | .050 |
| Block x Sample | 2 | 1.068 | .346 | .012 | 0.210 | .810 | .002 |
| Block x Age Group x Sample | 4 | 0.055 | .994 | .001 | 0.922 | .453 | .021 |
| Age Group | 2 | 0.160 | .852 | .004 | 0.229 | .796 | .005 |
| Sample | 1 | 0.108 | .743 | .001 | 0.025 | .874 | <.001 |
| Age Group x Sample | 1 | 2.054 | .134 | .046 | 0.093 | .912 | .002 |

### G.2.2. Stimulus Duration Manipulation

Table G.30

*Stimulus Duration Manipulation - RT & ACC: Results of 2x3x2 (and 2x3x2x2) repeated measures ANOVAs with the factors duration, level, age group (and sample group)*

| | | DV RT | | | DV ACC | | |
|---|---|---|---|---|---|---|---|
| | df | F | p | $\eta^2$ | F | p | $\eta^2$ |
| TD | | | | | | | |
| Duration | 1 | 7.122 | .001 | .100 | 1.380 | .257 | .030 |
| Duration x Age Group | 2 | 0.162 | .957 | .005 | 1.071 | .376 | .046 |
| Level | 2 | 41.624 | <.001 | .394 | 2.295 | .137 | .050 |
| Level x Age Grouop | 4 | 1.118 | .333 | .034 | 0.939 | .399 | .041 |
| Duration x Level | 2 | 0.434 | .649 | .007 | 2.619 | .079 | .056 |
| Duration x Level x Age Group | 4 | 0.382 | .821 | .012 | 2.378 | .058 | .098 |
| Age Group | 2 | 47.932 | <.001 | .600 | 4.574 | .016 | .172 |
| ASD | | | | | | | |
| Duration | 1 | 7.318 | .001 | .143 | 12.830 | <.001 | .230 |
| Duration x Age Group | 2 | 0.188 | .944 | .008 | 1.672 | .164 | .072 |
| Level | 2 | 40.571 | <.001 | .480 | 4.056 | .050 | .086 |
| Level x Age Group | 4 | 1.538 | .226 | .065 | 0.093 | .911 | .004 |
| Duration x Level | 2 | 2.292 | .107 | .050 | 9.231 | <.001 | .177 |
| Duration x Level x Age Group | 4 | 2.779 | .032 | .112 | 0.480 | .750 | .022 |
| Age Group | 2 | 3.947 | .027 | .152 | 6.087 | .005 | .221 |
| ASD & AmTD | | | | | | | |
| Duration | 1 | 8.611 | <.001 | .092 | 4.183 | .017 | .057 |
| Duration x Age Group | 2 | 0.306 | .874 | .007 | 1.471 | .214 | .041 |
| Duration x Sample | 1 | 3.952 | .021 | .044 | 7.835 | .001 | .102 |
| Duration x Age Group x Sample | 2 | 0.095 | .984 | .002 | 2.118 | .082 | .058 |
| Level | 2 | 65.058 | <.001 | .434 | 1.031 | .313 | .015 |
| Level x Age Group | 4 | 0.269 | .765 | .006 | 0.014 | .987 | <.001 |
| Level x Sample | 2 | 0.675 | .413 | .008 | 3.545 | .064 | .049 |
| Level x Age Group x Sample | 4 | 3.534 | .034 | .077 | 0.250 | .779 | .007 |
| Duration x Level | 2 | 0.421 | .657 | .005 | 6.370 | .002 | .085 |
| Duration x Level x Age Group | 4 | 2.192 | .072 | .049 | 1.873 | .119 | .052 |
| Duration x Level x Sample | 2 | 1.693 | .187 | .020 | 3.433 | .035 | .047 |
| Duration x Level x Age Group x Sample | 4 | 0.589 | .671 | .014 | 0.358 | .838 | .010 |
| Age Group | 2 | 18.247 | <.001 | .300 | 8.812 | <.001 | .203 |
| Sample | 1 | 0.157 | .693 | .002 | 4.645 | .035 | .063 |
| Age Group x Sample | 1 | 1.708 | .187 | .039 | 0.704 | .498 | .020 |

Table G.31

*Stimulus Duration Manipulation - BI: Results of 3x2 (and 3x2x2) repeated measures ANOVAs with the factors duration, age group (and sample group)*

| | | BI RT | | | BI ACC | | |
|---|---|---|---|---|---|---|---|
| | df | F | p | $\eta^2$ | F | p | $\eta^2$ |
| TD | | | | | | | |
| Duration | 2 | 1.630 | .202 | .036 | 2.839 | .064 | .061 |
| Duration x Age Group | 4 | 0.581 | .677 | .026 | 2.360 | .059 | .097 |
| Age Group | 2 | 0.791 | .460 | .035 | 0.388 | .681 | .017 |
| ASD | | | | | | | |
| Duration | 2 | 2.501 | .088 | .055 | 10.137 | <.001 | .191 |
| Duration x Age Group | 4 | 3.381 | .013 | .136 | 0.887 | .476 | .040 |
| Age Group | 2 | 1.484 | .238 | .065 | 0.172 | .842 | .008 |
| ASD & AmTD | | | | | | | |
| Duration | 2 | 0.703 | .497 | .010 | 7.192 | .001 | .094 |
| Duration x Age Group | 4 | 2.245 | .067 | .061 | 2.661 | .035 | .072 |
| Duration x Sample | 2 | 3.471 | .034 | .048 | 2.788 | .065 | .039 |
| Duration x Age Group x Sample | 4 | 1.052 | .383 | .030 | 0.167 | .955 | .005 |
| Age Group | 2 | 0.493 | .613 | .014 | 0.082 | .921 | .002 |
| Sample | 1 | 0.684 | .411 | .010 | 4.865 | .031 | .066 |
| Age Group x Sample | 1 | 4.223 | .019 | .109 | 0.738 | .482 | .021 |

## G.2.3. Level Switch & Stimulus Duration

Table G.32

*Level Switch & Stimulus Duration - RT & ACC: Results of 3x2x3x3 (and 3x2x3x3x2) repeated measures ANOVAs with the factors duration, level, priming, age group (and sample group)*

| | | DV RT | | | DV ACC | | |
|---|---|---|---|---|---|---|---|
| | *df* | *F* | *p* | $\eta^2$ | *F* | *p* | $\eta^2$ |
| TD | | | | | | | |
| Duration | 1 | 6.982 | .002 | .134 | 6.747 | .002 | .130 |
| Duration x Age Group | 2 | 1.387 | .245 | .058 | 1.254 | .294 | .053 |
| Level | 2 | 18.174 | <.001 | .288 | 4.844 | .033 | .097 |
| Level x Age Grouop | 4 | 1.900 | .161 | .078 | 2.110 | .133 | .086 |
| Priming | 2 | 59.407 | <.001 | .569 | 21.698 | <.001 | .325 |
| Priming x Age Group | 4 | 2.246 | .070 | .091 | 1.497 | .210 | .062 |
| Duration x Level | 4 | 1.950 | .148 | .042 | 1.329 | .270 | .029 |
| Duration x Level x Age Group | 4 | 0.472 | .756 | .021 | 0.984 | .420 | .042 |
| Duration x Priming | 4 | 0.932 | .447 | .020 | 0.867 | .485 | .019 |
| Duration x Priming x Age Group | 8 | 1.046 | .403 | .044 | 0.298 | .966 | .013 |
| Level x Priming | 2 | 0.529 | .591 | .012 | 0.075 | .928 | .002 |
| Level x Priming x Age Group | 4 | 0.676 | .611 | .029 | 0.166 | .955 | .007 |
| Duration x Level x Priming | 4 | 1.116 | .350 | .024 | 1.279 | .280 | .028 |
| Duration x Level x Priming x Age Group | 8 | 1.236 | .280 | .052 | 1.849 | .071 | .076 |
| Age Group | 2 | 27.853 | <.001 | .553 | 9.039 | .001 | .287 |
| ASD | | | | | | | |
| Duration | 1 | 2.814 | .066 | .063 | 14.319 | <.001 | .254 |
| Duration x Age Group | 2 | 0.598 | .665 | .028 | 1.051 | .386 | .048 |
| Level | 2 | 36.932 | <.001 | .468 | 8.907 | .005 | .175 |
| Level x Age Grouop | 4 | 0.650 | .527 | .030 | 0.037 | .964 | .002 |
| Priming | 2 | 65.464 | <.001 | .609 | 13.086 | <.001 | .238 |
| Priming x Age Group | 4 | 2.701 | .036 | .114 | 2.513 | .048 | .107 |
| Duration x Level | 4 | 0.380 | .685 | .009 | 5.881 | .004 | .123 |
| Duration x Level x Age Group | 4 | 2.190 | .077 | .094 | 0.474 | .755 | .022 |
| Duration x Priming | 4 | 2.597 | .038 | .058 | 1.827 | .126 | .042 |
| Duration x Priming x Age Group | 8 | 0.486 | .865 | .023 | 0.762 | .637 | .035 |
| Level x Priming | 2 | 3.007 | .055 | .067 | 1.947 | .149 | .044 |
| Level x Priming x Age Group | 4 | 0.324 | .861 | .015 | 1.692 | .159 | .075 |
| Duration x Level x Priming | 4 | 1.128 | .345 | .026 | 0.939 | .443 | .022 |
| Duration x Level x Priming x Age Group | 8 | 0.360 | .940 | .017 | 0.218 | .987 | .010 |
| Age Group | 2 | 6.830 | .003 | .245 | 4.750 | .014 | .184 |
| ASD & AmTD | | | | | | | |
| Duration | 1 | 2.415 | .093 | .034 | 9.530 | <.001 | .121 |
| Duration x Sample | 2 | 2.503 | .086 | .035 | 5.332 | .006 | .072 |
| Duration x Age Group | 4 | 1.125 | .347 | .032 | 0.779 | .541 | .022 |
| Duration x Sample x Age Group | 4 | 0.335 | .854 | .010 | 1.224 | .304 | .034 |
| Level | 1 | 53.385 | <.001 | .436 | 5.769 | .019 | .077 |
| Level x Sample | 1 | 1.567 | .215 | .022 | 1.909 | .172 | .027 |
| Level x Age Grouop | 2 | 3.359 | .041 | .089 | 0.209 | .812 | .006 |
| Level x Sample x Age Group | 2 | 3.511 | .035 | .092 | 0.093 | .911 | .003 |
| Priming | 2 | 98.668 | <.001 | .588 | 26.902 | <.001 | .281 |
| Priming x Sample | 2 | 1.358 | .261 | .019 | 0.163 | .850 | .002 |
| Priming x Age Group | 4 | 4.188 | .003 | .108 | 2.025 | .094 | .055 |
| Priming x Sample x Age Grouop | 4 | 0.254 | .907 | .007 | 0.553 | .697 | .016 |
| Duration x Level | 2 | 0.991 | .374 | .014 | 1.139 | .323 | .016 |
| Duration x Level x Sample | 2 | 2.750 | .067 | .038 | 4.072 | .019 | .056 |
| Duration x Level x Age Group | 4 | 2.669 | .035 | .072 | 1.005 | .407 | .028 |
| Duration x Level x Sample x Age Group | 4 | 0.757 | .555 | .021 | 0.555 | .695 | .016 |
| Duration x Priming | 4 | 3.284 | .012 | .045 | 1.398 | .235 | .020 |
| Duration x Priming x Sample | 4 | 0.621 | .648 | .009 | 0.977 | .421 | .014 |
| Duration x Priming x Age Group | 8 | 1.979 | .049 | .054 | 2.135 | .033 | .058 |
| Duration x Priming x Sample x Age Group | 8 | 1.592 | .127 | .044 | 0.738 | .658 | .021 |
| Level x Priming | 2 | 2.761 | .067 | .038 | 0.633 | .533 | .009 |
| Level x Priming x Sample | 2 | 0.796 | .453 | .011 | 0.770 | .465 | .011 |
| Level x Priming x Age Group | 4 | 0.578 | .679 | .016 | 1.547 | .192 | .043 |
| Level x Priming x Sample x Age Group | 4 | 0.361 | .836 | .010 | 0.632 | .640 | .018 |
| Duration x Level x Priming | 4 | 0.840 | .501 | .012 | 2.770 | .028 | .039 |
| Duration x Level x Priming x Sample | 4 | 0.334 | .855 | .005 | 0.718 | .580 | .010 |
| Duration x Level x Priming x Age Group | 8 | 0.534 | .831 | .015 | 1.321 | .233 | .037 |
| Duration x Level x Priming x Sample x Age Group | 8 | 0.169 | .995 | .005 | 0.962 | .466 | .027 |
| Sample | 1 | 1.596 | .211 | .023 | 3.316 | .073 | .046 |
| Age Group | 2 | 16.387 | <.001 | .322 | 7.046 | .002 | .170 |
| Sample x Age Group | 2 | 0.250 | .779 | .007 | 0.922 | .402 | .026 |

Table G.33

*Level Switch & Stimulus Duration - PESC: Results of 3x2x3x3 (and 3x2x3x3x2) repeated measures ANOVAs with the factors duration, level, age group (and sample group)*

| | | DV PESCRT | | | DV PESCACC | | |
|---|---|---|---|---|---|---|---|
| | df | F | p | $\eta^2$ | F | p | $\eta^2$ |
| TD | | | | | | | |
| Duration | 1 | 0.065 | .937 | .001 | 0.622 | .539 | .014 |
| Duration x Age Group | 2 | 0.895 | .470 | .037 | 0.314 | .868 | .014 |
| Level | 2 | 0.546 | .464 | .012 | 0.121 | .729 | .003 |
| Level x Age Grouop | 4 | 0.908 | .411 | .038 | 0.007 | .994 | <.001 |
| Duration x Level | 2 | 0.272 | .763 | .006 | 2.131 | .125 | .045 |
| Duration x Level x Age Group | | 1.587 | .184 | .065 | 2.482 | .049 | .099 |
| Age Group | 2 | 4.838 | .012 | .174 | 0.888 | .419 | .038 |
| ASD | | | | | | | |
| Duration | 1 | 1.120 | .331 | .026 | 2.530 | .086 | .057 |
| Duration x Age Group | 2 | 0.391 | .815 | .018 | 1.319 | .270 | .059 |
| Level | 2 | 5.287 | .027 | .112 | 3.490 | .069 | .077 |
| Level x Age Grouop | 4 | 0.401 | .672 | .019 | 1.556 | .223 | .069 |
| Duration x Level | 4 | 0.739 | .481 | .017 | 0.703 | .498 | .016 |
| Duration x Level x Age Group | 4 | 0.386 | .818 | .018 | 0.065 | .992 | .003 |
| Age Group | 2 | 3.338 | .045 | .137 | 1.999 | .148 | .087 |
| ASD & AmTD | | | | | | | |
| Duration | 1 | 1.302 | .275 | .018 | 0.807 | .448 | .012 |
| Duration x Sample | 2 | 0.948 | .390 | .013 | 1.238 | .293 | .018 |
| Duration x Age Group | 4 | 1.412 | .233 | .039 | 2.047 | .091 | .056 |
| Duration x Sample x Age Group | 4 | 2.135 | .080 | .058 | 0.992 | .414 | .028 |
| Level | 1 | 2.811 | .098 | .039 | 1.263 | .265 | .018 |
| Level x Sample | 1 | 2.867 | .095 | .039 | 1.340 | .251 | .019 |
| Level x Age Grouop | 2 | 0.340 | .713 | .010 | 0.678 | .511 | .019 |
| Level x Sample x Age Group | 2 | 0.376 | .688 | .011 | 0.695 | .502 | .020 |
| Duration x Level | 2 | 1.151 | .319 | .016 | 2.749 | .068 | .038 |
| Duration x Level x Sample | 2 | 0.020 | .980 | <.001 | 1.277 | .282 | .018 |
| Duration x Level x Age Group | 4 | 1.120 | .350 | .031 | 0.619 | .650 | .018 |
| Duration x Level x Sample x Age Group | 4 | 0.362 | .835 | .010 | 0.586 | .673 | .017 |
| Sample | 1 | 3.076 | .084 | .042 | 0.160 | .691 | .002 |
| Age Group | 2 | 6.088 | .004 | .148 | 1.782 | .176 | .049 |
| Sample x Age Group | 2 | 0.176 | .839 | .005 | 0.364 | .696 | .010 |

### G.2.4. Level Switch & Contingency

Table G.34

*Level Switch & Contingency - RT & ACC: Results of 2x3x2 repeated measures ANOVAs with the factors level, contingency, age group for TD and ASD*

| | | DV RT | | | DV ACC | | |
|---|---|---|---|---|---|---|---|
| | df | F | p | $\eta^2$ | F | p | $\eta^2$ |
| TD | | | | | | | |
| Contingency | 2 | 36.228 | <.001 | .365 | 4.062 | .048 | .061 |
| Contingency x Age Group | 4 | 3.757 | .029 | .107 | 0.028 | .972 | .001 |
| Level | 1 | 12.956 | .001 | .171 | 3.308 | .074 | .050 |
| Level x Age Group | 2 | 0.735 | .484 | .023 | 3.620 | .032 | .103 |
| Priming | 2 | 59.192 | <.001 | .484 | 22.303 | <.001 | .261 |
| Priming x Age Group | 4 | 0.862 | .489 | .027 | 2.030 | .094 | .061 |
| Contingency x Level | 2 | 1.622 | .208 | .025 | 1.498 | .226 | .023 |
| Contingency x Level x Age Group | 4 | 1.696 | .192 | .051 | 0.500 | .609 | .016 |
| Contingency x Priming | 2 | 0.629 | .535 | .010 | 0.639 | .529 | .010 |
| Contingency x Priming x Age Group | 4 | 1.002 | .409 | .031 | 1.229 | .302 | .038 |
| Level x Priming | 2 | 0.107 | .899 | .002 | 0.330 | .719 | .005 |
| Level x Priming x Age Group | 4 | 0.825 | .512 | .026 | 1.449 | .222 | .044 |
| Contingency x Level x Priming | 2 | 0.168 | .846 | .003 | 0.312 | .733 | .005 |
| Contingency x Level x Priming x Age Group | 4 | 1.221 | .305 | .037 | 0.550 | .699 | .017 |
| Age Group | 2 | 30.832 | <.001 | .495 | 9.686 | <.001 | .235 |
| ASD | | | | | | | |
| Contingency | 2 | 15.476 | <.001 | .256 | 0.499 | .483 | .011 |
| Contingency x Age Group | 4 | 0.868 | .427 | .037 | 0.708 | .498 | .031 |
| Level | 1 | 8.719 | .005 | .162 | 3.359 | .073 | .069 |
| Level x Age Group | 2 | 1.422 | .252 | .059 | 1.627 | .208 | .067 |
| Priming | 2 | 30.398 | <.001 | .403 | 2.104 | .128 | .045 |
| Priming x Age Group | 4 | 1.449 | .224 | .061 | 2.129 | .084 | .086 |
| Contingency x Level | 2 | 2.134 | .151 | .045 | 1.947 | .170 | .041 |
| Contingency x Level x Age Group | 4 | 0.978 | .384 | .042 | 0.190 | .828 | .008 |
| Contingency x Priming | 2 | 1.031 | .361 | .022 | 0.458 | .634 | .010 |
| Contingency x Priming x Age Group | 4 | 1.780 | .140 | .073 | 3.578 | .009 | .137 |
| Level x Priming | 2 | 1.573 | .213 | .034 | 2.024 | .138 | .043 |
| Level x Priming x Age Group | 4 | 0.447 | .774 | .019 | 0.927 | .452 | .040 |
| Contingency x Level x Priming | 2 | 0.743 | .479 | .016 | 0.388 | .680 | .009 |
| Contingency x Level x Priming x Age Group | 4 | 0.303 | .875 | .013 | 0.334 | .854 | .015 |
| Age Group | 2 | 4.127 | .023 | .155 | 5.801 | .006 | .205 |

Table G.35

*Level Switch & Contingency – RT & ACC: Results of 2x3x2x2 repeated measures ANOVAs with the factors level, contingency, age group and sample group (ASD vs AmTD)*

| | | DV RT | | | DV ACC | | |
|---|---|---|---|---|---|---|---|
| | df | F | p | $\eta^2$ | F | p | $\eta^2$ |
| ASD & AmTD | | | | | | | |
| Contingency | 1 | 38.896 | <.001 | .314 | 1.670 | .200 | .019 |
| Contingency x Sample | 1 | 0.033 | .856 | <.001 | 0.036 | .849 | <.001 |
| Contingency x Age Group | 2 | 2.767 | .069 | .061 | 1.012 | .368 | .023 |
| Contingency x Age Group x Sample | 2 | 0.037 | .964 | .001 | 0.228 | .797 | .005 |
| Level | 1 | 16.210 | <.001 | .160 | 3.512 | .064 | .040 |
| Level x Sample | 1 | 0.096 | .757 | .001 | 0.173 | .679 | .002 |
| Level x Age Group | 2 | 0.141 | .868 | .003 | 3.389 | .038 | .074 |
| Level x Age Group x Sample | 2 | 1.250 | .292 | .029 | 0.858 | .428 | .020 |
| Priming | 2 | 64.538 | <.001 | .432 | 12.975 | <.001 | .132 |
| Priming x Sample | 2 | 2.298 | .104 | .026 | 2.095 | .126 | .024 |
| Priming x Age Group | 4 | 2.320 | .059 | .052 | 1.927 | .108 | .043 |
| Priming x Age Group x Sample | 4 | 0.321 | .864 | .007 | 1.990 | .098 | .045 |
| Contingency x Level | 1 | 1.658 | .201 | .019 | 0.148 | .701 | .002 |
| Contingency x Level x Sample | 1 | 0.849 | .359 | .010 | 2.167 | .145 | .025 |
| Contingency x Level x Age Group | 2 | 0.843 | .434 | .019 | 0.162 | .851 | .004 |
| Contingency x Level x Age Group x Sample | 2 | 0.692 | .503 | .016 | 0.445 | .642 | .010 |
| Contingency x Priming | 2 | 0.252 | .778 | .003 | 1.077 | .343 | .013 |
| Contingency x Priming x Sample | 2 | 2.101 | .126 | .024 | 0.114 | .892 | .001 |
| Contingency x Priming x Age Group | 4 | 1.305 | .270 | .030 | 3.654 | .007 | .079 |
| Contingency x Priming x Age Group x Sample | 4 | 1.768 | .137 | .040 | 2.064 | .088 | .046 |
| Level x Priming | 2 | 0.217 | .805 | .003 | 2.646 | .074 | .030 |
| Level x Priming x Sample | 2 | 2.021 | .136 | .023 | 0.292 | .747 | .003 |
| Level x Priming x Age Group | 4 | 0.633 | .640 | .015 | 0.630 | .642 | .015 |
| Level x Priming x Age Group x Sample | 4 | 0.117 | .976 | .003 | 1.460 | .217 | .033 |
| Contingency x Level x Priming | 2 | 0.983 | .376 | .011 | 0.337 | .714 | .004 |
| Contingency x Level x Priming x Sample | 2 | 0.199 | .820 | .002 | 0.623 | .537 | .007 |
| Contingency x Level x Priming x Age Group | 4 | 0.516 | .724 | .012 | 0.694 | .597 | .016 |
| Contingency x Level x Priming x Age Group x Sample | 4 | 0.143 | .966 | .003 | 0.259 | .904 | .006 |
| Sample | 1 | 0.125 | .724 | .001 | 1.198 | .277 | .014 |
| Age Group | 2 | 15.316 | <.001 | .265 | 10.782 | <.001 | .202 |
| Sample x Age Group | 2 | 0.969 | .384 | .022 | 0.358 | .700 | .008 |

### G.2.5. Bias and AQ

Table G.36

*Bias and AQ - Results of 5x2 (and 5x2x2) repeated measures ANOVAs with the factors block, age group (and sample group)*

| | | DV BIRT | | | DV BIACC | | |
|---|---|---|---|---|---|---|---|
| | df | F | p | $\eta^2$ | F | p | $\eta^2$ |
| TD | | | | | | | |
| Block | 4 | 19.636 | <.001 | .412 | 5.171 | .001 | .156 |
| Block x Age Group | 4 | 2.729 | .033 | .089 | 1.361 | .252 | .046 |
| Block x AQ Group | 4 | 6.108 | <.001 | .179 | 2.105 | .085 | .070 |
| Block x Age Group x AQ Group | 4 | 1.863 | .122 | .062 | 0.582 | .676 | .020 |
| Age Group | 1 | 3.155 | .087 | .101 | 0.646 | .428 | .023 |
| AQ Group | 1 | 0.460 | .503 | .016 | 0.384 | .541 | .014 |
| Age Group x AQ Group | 1 | 0.245 | .624 | .009 | 0.380 | .543 | .013 |
| ASD | | | | | | | |
| Block | 4 | 10.948 | <.001 | .281 | 6.364 | <.001 | .185 |
| Block x Age Group | 4 | 2.221 | .071 | .073 | 1.737 | .147 | .058 |
| Block x AQ Group | 4 | 2.056 | .091 | .068 | 1.612 | .176 | .054 |
| Block x Age Group x AQ Group | 4 | 2.182 | .076 | .072 | 2.010 | .098 | .067 |
| Age Group | 1 | 0.129 | .723 | .005 | 1.100 | .303 | .038 |
| AQ Group | 1 | 0.564 | .459 | .020 | 1.375 | .251 | .047 |
| Age Group x AQ Group | 1 | 0.081 | .778 | .003 | 0.403 | .531 | .014 |
| ASD & AmTD | | | | | | | |
| Block | 4 | 28.594 | <.001 | .338 | 10.757 | <.001 | .161 |
| Block x Sample | 4 | 0.799 | .527 | .014 | 2.389 | .052 | .041 |
| Block x Age Group | 4 | 4.428 | .002 | .073 | 2.557 | .040 | .044 |
| Block x AQ Group | 4 | 1.427 | .226 | .025 | 2.356 | .055 | .040 |
| Block x Sample x Age Group | 4 | 0.454 | .770 | .008 | 1.011 | .403 | .018 |
| Block x Sample x AQ Group | 4 | 6.180 | <.001 | .099 | 1.301 | .271 | .023 |
| Block x Age Group x AQ Group | 4 | 1.334 | .258 | .023 | 1.615 | .171 | .028 |
| Block x Sample x Age Group x AQ Group | 4 | 2.757 | .029 | .047 | 2.104 | .081 | .036 |
| Sample | 1 | 0.007 | .934 | <.001 | 0.023 | .881 | <.001 |
| Age Group | 1 | 0.929 | .339 | .016 | 0.082 | .775 | .001 |
| AQ Group | 1 | 1.010 | .319 | .018 | 0.251 | .619 | .004 |
| Sample x Age Group | 1 | 2.186 | .145 | .038 | 1.752 | .191 | .030 |
| Sample x AQ Group | 1 | 0.005 | .943 | <.001 | 1.689 | .199 | .029 |
| Age Group x AQ Group | 1 | 0.019 | .892 | <.001 | 0.008 | .929 | <.001 |
| Sample x Age Group x AQ Group | 1 | 0.296 | .588 | .005 | 0.783 | .380 | .014 |

# Appendix H Descriptive and Inferential Statistics in LANTA (Chapter 9)

## H.1. AMBWORD

### H.1.1. Descriptive Statistics

Table H.37

*Descriptive Statistics for TD and ASD in AMBWORD*

| | Child | | Adolescent | | Adult | | Overall | |
|---|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| TD | | | | | | | | |
| *Reaction Times (ms)* | | | | | | | | |
| Dominant | 1045 | 322 | 641 | 73 | 638 | 138 | 765 | 274 |
| Subordinate | 1428 | 440 | 821 | 114 | 825 | 146 | 1010 | 386 |
| Neutral | 1359 | 488 | 777 | 121 | 753 | 128 | 948 | 398 |
| *Accuracy (%)* | | | | | | | | |
| Dominant | 95.5 | 5.6 | 98.9 | 2.3 | 99.5 | 1.6 | 98.0 | 3.9 |
| Subordinate | 85.3 | 10.0 | 94.1 | 5.9 | 97 | 4.6 | 92.4 | 8.5 |
| Neutral | 95.2 | 5.5 | 97.5 | 4.5 | 98.4 | 3.8 | 97.1 | 4.8 |
| *Dominant Advantage* | | | | | | | | |
| DAS-RT | 1.38 | 0.19 | 1.28 | 0.09 | 1.31 | 0.15 | 1.32 | 0.15 |
| DAS-ACC | 1.13 | 0.13 | 1.05 | 0.07 | 1.03 | 0.05 | 1.07 | 0.10 |
| ASD | | | | | | | | |
| *Reaction Times (ms)* | | | | | | | | |
| Dominant | 1226 | 462 | 768 | 156 | 794 | 185 | 888 | 326 |
| Subordinate | 1653 | 511 | 1036 | 242 | 1015 | 233 | 1176 | 417 |
| Neutral | 1461 | 460 | 948 | 158 | 869 | 179 | 1039 | 356 |
| *Accuracy (%)* | | | | | | | | |
| Dominant | 94.8 | 7.9 | 99.1 | 2.9 | 98.3 | 3.2 | 97.7 | 4.9 |
| Subordinate | 83.6 | 11.6 | 97.1 | 4.9 | 96.4 | 5.2 | 93.6 | 9.0 |
| Neutral | 97.5 | 5.3 | 98.4 | 4.4 | 99.7 | 1.2 | 98.7 | 3.8 |
| *Dominant Advantage* | | | | | | | | |
| DAS-RT | 1.38 | 0.21 | 1.35 | 0.15 | 1.28 | 0.11 | 1.33 | 0.16 |
| DAS-ACC | 1.15 | 0.15 | 1.02 | 0.04 | 1.02 | 0.05 | 1.05 | 0.10 |

## H.1.2. Inferential statistics

Table H.38

*TD: ANOVA statistics for the task AMBWORD*

| | *df (factor, error)* | *F* | *p* | $\eta^2$ |
|---|---|---|---|---|
| *Reaction Time* | | | | |
| type | 1.89, 122.873 | 137.039 | <.001 | .678 |
| age group | 2, 65 | 48.322 | <.001 | .598 |
| type * age group | 3,781, 122.873 | 1.01 | .402 | .03 |
| *Accuracy* | | | | |
| type | 1.696, 110.208 | 28.201 | <.001 | .303 |
| age group | 2, 65 | 19.371 | <.001 | .373 |
| type * age group | 3.391, 110.208 | 5.529 | .001 | .145 |
| *DAS-RT* | | | | |
| age group | 2.65 | 1.965 | .148 | .057 |
| *DAS-ACC* | | | | |
| age group | 2, 65 | 7.707 | .001 | .192 |

*Note.* Presented are results of 3x3 repeated measures ANOVAs with the factors type and age group for the DVs RT or accuracy, and results of one-way ANOVAs with the factor age group for the DAS-RT and DAS-ACC. Huynh-Feldt corrected dfs where appropriate. Post-hoc test results are presented separately.

Table H.39

*TD: Results of post-hoc tests/ pairwise comparisons for the task AMBWORD*

| | | dom vs neu | | dom vs sub | | neu vs sub | |
|---|---|---|---|---|---|---|---|
| DV | Factor: result | *p* | *d* | *p* | *d* | *p* | *d* |
| *RT* | type: dominant < neutral < subordinate | < .001 | -0.55 | < .001 | -.74 | < .001 | .16 |
| ACC | type: dominant = neutral > subordinate | .478 | .21 | <.001 | .91 | <.001 | -.71 |
| | Interaction of type and age group | | | | | | |
| | child: dom = neu, dom > sub, neu > sub | .828[a] | 0.05 | <.001[a] | 1.31 | <.001[a] | 1.28 |
| | adolescent: dom = neu, dom > sub, neu = sub | .295[a] | 0.41 | .002[a] | 1.17 | .039[a] | .66 |
| | adult: dom = neu, dom > sub, neu = sub | .203[a] | 0.41 | .008[a] | 0.81 | .247[a] | .33 |
| | | child vs adolescent | | child vs adult | | adolescent vs adult | |
| RT | age group: child < adolescent = adult | < .001 | 2.32 | < .001 | 2.35 | 1 | .03 |
| ACC | age group: child < adolescent = adult | < .001 | -1.37 | < .001 | -1.78 | .443 | -.44 |
| *DSR-ACC* | age group: child > adolescent = adult | .018 | .80 | .001 | 1.11 | 1 | .33 |

*Note.* a) Bonferroni corrected alpha level $\alpha = .025$. If not otherwise stated, Bonferroni adjusted *p*-values are reported. Abbreviations: dom = dominant, neu = neutral, sub = subordinate. *d*: effect size

Table H.40

*ASD vs AmTD: ANOVA statistics for the task AMBWORD*

| | *df (factor, error)* | *F* | *p* | $\eta^2$ |
|---|---|---|---|---|
| *Reaction Time* | | | | |
| type (dominant vs subordinate) | 1.88, 167.51 | 191.832 | <.001 | .683 |
| type * age group | 3.76, 167.51 | 1.440 | .225 | .031 |
| type * sample group | 1.88, 167.51 | .326 | .709 | .004 |
| type * age group * sample group | 3.76, 167.51 | .926 | .446 | .020 |
| age group | 2, 89 | 29.235 | <.001 | .396 |
| sample group | 1, 89 | 10.702 | .002 | .107 |
| age group * sample group | 2, 89 | .159 | .853 | .004 |
| *Accuracy* | | | | |
| type (dominant vs subordinate) | 1.74, 155.18 | 44.848 | <.001 | .335 |
| type * age group | 3.49, 155.18 | 12.734 | <.001 | .222 |
| type * sample group | 1.74, 155.18 | .888 | .401 | .010 |
| type * age group * sample group | 3.49, 155.18 | .636 | .616 | .014 |
| age group | 2, 89 | 22.044 | <.001 | .331 |
| sample group | 1, 89 | .010 | .919 | <.001 |
| age group * sample group | 2, 89 | 1.140 | .324 | .025 |
| *DAS (RT)* | | | | |
| age group | 2, 89 | 5.586 | .005 | .112 |
| sample group | 1, 89 | .152 | .697 | .002 |
| age group * sample group | 2, 89 | 1.446 | .241 | .031 |
| DAS (ACC) | | | | |
| age group | 2, 89 | 19.050 | <.001 | .300 |
| sample group | 1, 89 | .882 | .350 | .010 |
| age group * sample group | 2, 89 | .279 | .757 | .006 |

*Note*. Presented are results of 3x3 repeated measures ANOVAs with the factors type and age group for the DVs RT or accuracy, and results of one-way ANOVAs with the factor age group for the DAS. Huynh-Feldt corrected dfs where appropriate.

## H.2. AMBSENT

### H.2.1. Descriptive Statistics

Table H.41

*TD: Descriptive Statistics for the task AMBSENT*

| | | | | Child | | Adolescent | | Adult | | Overall | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Reaction Times (ms) | Facilitation Condition | Dominant | biased | 1074 | 291 | 642 | 146 | 634 | 176 | 773 | 290 |
| | | | neutral | 1204 | 273 | 695 | 138 | 761 | 382 | 875 | 358 |
| | | Subordinate | biased | 1288 | 411 | 721 | 158 | 706 | 236 | 891 | 386 |
| | | | neutral | 1463 | 432 | 833 | 175 | 891 | 426 | 1048 | 455 |
| | | CFR | dominant | 1.15 | 0.20 | 1.09 | 0.12 | 1.17 | 0.22 | 1.14 | 0.18 |
| | | | subordinate | 1.19 | 0.32 | 1.17 | 0.16 | 1.24 | 0.23 | 1.20 | 0.24 |
| | | TFS | overall | 305 | 511 | 164 | 146 | 312 | 429 | 260 | 391 |
| | Suppression Condition | Dominant | ambiguous | 1621 | 497 | 885 | 255 | 884 | 286 | 1112 | 491 |
| | | | unambiguous | 1502 | 292 | 870 | 217 | 852 | 226 | 1059 | 384 |
| | | Subordinate | ambiguous | 1496 | 364 | 833 | 193 | 824 | 281 | 1035 | 419 |
| | | | unambiguous | 1337 | 272 | 776 | 177 | 764 | 224 | 945 | 346 |
| | | CSR | dominant | 0.97 | 0.20 | 1.00 | 0.12 | 0.99 | 0.18 | 0.99 | 0.17 |
| | | | subordinate | 0.91 | 0.15 | 0.94 | 0.12 | 0.95 | 0.11 | 0.93 | 0.13 |
| | | TIS | overall | 0.10 | 0.16 | 0.04 | 0.11 | 0.05 | 0.13 | 0.06 | 0.13 |
| Accuracy (%) | Facilitation Condition | Dominant | biased | 92.1 | 5.8 | 96.6 | 4.0 | 97.9 | 4.0 | 95.7 | 5.2 |
| | | | neutral | 93.5 | 6.9 | 96.1 | 5.4 | 97.4 | 4.5 | 95.8 | 5.8 |
| | | Subordinate | biased | 85.9 | 8.2 | 94.5 | 8.1 | 98.1 | 3.6 | 93.1 | 8.5 |
| | | | neutral | 69.0 | 21.8 | 86.8 | 10.9 | 92.0 | 10.5 | 83.1 | 17.7 |
| | | CFR | dominant | 0.99 | 0.11 | 1.01 | 0.05 | 1.01 | 0.05 | 1.00 | 0.07 |
| | | | subordinate | 1.39 | 0.52 | 1.10 | 0.17 | 1.08 | 0.13 | 1.18 | 0.34 |
| | | TFS | overall | 0.16 | 0.27 | 0.08 | 0.15 | 0.07 | 0.11 | 0.10 | 0.18 |
| | Suppression Condition | Dominant | ambiguous | 77.8 | 17.1 | 87.8 | 15.1 | 93.5 | 6.0 | 86.7 | 14.7 |
| | | | unambiguous | 94.9 | 6.6 | 97.8 | 3.7 | 98.1 | 3.5 | 97.0 | 4.9 |
| | | Subordinate | ambiguous | 75.2 | 16.7 | 86.1 | 18.4 | 88.6 | 13.9 | 83.6 | 17.2 |
| | | | unambiguous | 97.1 | 4.2 | 99.5 | 1.6 | 99.5 | 2.3 | 98.8 | 3.0 |
| | | CSR | dominant | 0.82 | 0.18 | 0.90 | 0.14 | 0.95 | 0.07 | 0.89 | 0.15 |
| | | | subordinate | 0.77 | 0.16 | 0.87 | 0.19 | 0.89 | 0.14 | 0.85 | 0.17 |
| | | TIS | overall | 0.21 | 0.15 | 0.12 | 0.16 | 0.08 | 0.08 | 0.13 | 0.14 |

Table H.42

*ASD: Descriptive Statistics for the task AMBSENT*

| | | | | Child | | Adolescent | | Adult | | Overall | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | M | SD | M | SD | M | SD | M | SD |
| Reaction Times (ms) | Facilitation Condition | Dominant | biased | 1318 | 404 | 807 | 407 | 839 | 255 | 943 | 406 |
| | | | neutral | 1364 | 448 | 914 | 494 | 962 | 347 | 1041 | 459 |
| | | Subordinate | biased | 1462 | 503 | 898 | 379 | 961 | 428 | 1059 | 480 |
| | | | neutral | 1524 | 476 | 1138 | 545 | 1063 | 324 | 1201 | 479 |
| | | CFR | dominant | 1.07 | 0.31 | 1.14 | 0.18 | 1.14 | 0.17 | 1.12 | 0.21 |
| | | | subordinate | 1.07 | 0.16 | 1.26 | 0.21 | 1.15 | 0.21 | 1.17 | 0.21 |
| | | TFS | overall | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| | Suppression Condition | Dominant | ambiguous | 1734 | 405 | 1046 | 339 | 1137 | 364 | 1248 | 454 |
| | | | unambiguous | 1836 | 606 | 1076 | 445 | 1011 | 195 | 1232 | 533 |
| | | Subordinate | ambiguous | 1643 | 496 | 1021 | 295 | 1008 | 198 | 1155 | 410 |
| | | | unambiguous | 1836 | 606 | 1076 | 445 | 1011 | 195 | 1232 | 533 |
| | | CSR | dominant | 1.06 | 0.23 | 1.03 | 0.17 | 0.93 | 0.18 | 1.00 | 0.19 |
| | | | subordinate | 0.94 | 0.15 | 0.95 | 0.17 | 0.89 | 0.12 | 0.92 | 0.14 |
| | | TIS | overall | 0.04 | 0.11 | 0.03 | 0.14 | 0.13 | 0.19 | 0.07 | 0.16 |
| Accuracy (%) | Facilitation Condition | Dominant | biased | 95.0% | 6.2% | 98.4% | 3.2% | 94.9% | 11.0% | 96.2% | 7.9% |
| | | | neutral | 90.6% | 11.3% | 96.8% | 5.8% | 94.5% | 15.8% | 94.4% | 12.0% |
| | | Subordinate | biased | 90.3% | 10.6% | 98.4% | 4.2% | 94.2% | 15.7% | 94.8% | 11.7% |
| | | | neutral | 83.2% | 13.9% | 90.2% | 12.8% | 85.3% | 21.8% | 86.6% | 17.1% |
| | | CFR | dominant | 1.06 | 0.12 | 1.02 | 0.06 | 1.03 | 0.17 | 1.03 | 0.13 |
| | | | subordinate | 1.11 | 0.23 | 1.12 | 0.19 | 1.18 | 0.37 | 1.14 | 0.28 |
| | | TFS | overall | 1.08 | 0.17 | 1.06 | 0.09 | 1.09 | 0.23 | 1.08 | 0.17 |
| | Suppression Condition | Dominant | ambiguous | 75.5% | 26.9% | 92.7% | 12.3% | 89.4% | 14.2% | 87.3% | 18.4% |
| | | | unambiguous | 89.6% | 11.5% | 97.5% | 4.4% | 98.1% | 4.5% | 95.8% | 7.5% |
| | | Subordinate | ambiguous | 64.5% | 33.8% | 88.4% | 14.8% | 89.7% | 16.0% | 83.2% | 23.3% |
| | | | unambiguous | 93.6% | 10.0% | 99.7% | 1.3% | 99.2% | 2.0% | 98.0% | 5.6% |
| | | CSR | dominant | 0.82 | 0.25 | 0.95 | 0.11 | 0.91 | 0.14 | 0.90 | 0.17 |
| | | | subordinate | 0.66 | 0.33 | 0.89 | 0.15 | 0.90 | 0.16 | 0.84 | 0.23 |
| | | TIS | overall | 0.26 | 0.28 | 0.08 | 0.11 | 0.09 | 0.14 | 0.13 | 0.19 |

### H.2.2. Inferential Statistics

Table H.43

*TD: ANOVA Results in the task AMBSENT for DVs: RT and ACC*

| | | DV: Reaction Time | | | DV: Accuracy | | |
|---|---|---|---|---|---|---|---|
| | *df* | *F* | *p* | $\eta^2$ | *F* | *p* | $\eta^2$ |
| *Facilitation condition* | | | | | | | |
| context | 1 | 61.210 | <.001 | .485 | 20.852 | <.001 | .243 |
| context * age group | 2 | .908 | .408 | .027 | 1.492 | .232 | .044 |
| dominance | 1 | 147.513 | <.001 | .694 | 71.519 | <.001 | .524 |
| dominance * age group | 2 | .330 | .720 | .010 | 16.582 | <.001 | .338 |
| context * dominance | 1 | 2.368 | .129 | .035 | 28.963 | <.001 | .308 |
| context * dominance * age group | 2 | .772 | .466 | .023 | 4.106 | .021 | .112 |
| age group | 2 | 32.729 | <.001 | .502 | 24.410 | <.001 | .429 |
| *Supression condition* | | | | | | | |
| ambiguity | 1 | 9.305 | .003 | .125 | 70.535 | <.001 | .520 |
| ambiguity *age group | 2 | .206 | .814 | .006 | 4.960 | .010 | .132 |
| dominance | 1 | 68.545 | <.001 | .513 | 0.673 | .415 | .010 |
| dominance * age group | 2 | .574 | .566 | .017 | .500 | .609 | .015 |
| ambiguity * dominance | 1 | 7.431 | .008 | .103 | 9.524 | .003 | .128 |
| ambiguity * dominance * age group | 2 | .221 | .802 | .007 | .286 | .752 | .009 |
| age group | 2 | 42.041 | <.001 | .564 | 7.597 | .001 | .189 |

*Note.* $N = 68$. $df_{error} = 65$. Analysis methods: 2x3x2 repeated measures ANOVAs in the contextual facilitation (factors: context type, dominance, age group) and suppression conditions (factors: ambiguity, dominance, age group)

Table H.44

*TD: ANOVA Results in the task AMBSENT for DVs: CFR, CSR, TFR and TIS for RT and ACC*

| | | | Reaction Time | | | Accuracy | | |
|---|---|---|---|---|---|---|---|---|
| | | *df* | *F* | *p* | $\eta^2$ | *F* | *p* | $\eta^2$ |
| *Facilitation Condition* | | | | | | | | |
| DV: CFR | dominance | 1 | 4.079 | .048 | .059 | 25.024 | <.001 | .278 |
| | age group | 2 | 1.009 | .37 | .030 | 4.999 | .101 | .133 |
| | dominance * age group | 2 | .170 | .844 | .005 | 7.894 | .001 | .195 |
| DV: TFR | age group | 2 | 1.003 | .372 | .030 | 2.703 | .075 | .077 |
| *Suppression Condition* | | | | | | | | |
| *DV: CSR* | dominance | 1 | 6.349 | .014 | .089 | 8.935 | .004 | .121 |
| | age group | 2 | .402 | .671 | .012 | 5.035 | .009 | .134 |
| | dominance * age group | 2 | .053 | .948 | .002 | .419 | .659 | .013 |
| DV: TIS | age group | 2 | .994 | .376 | .030 | 5.037 | .009 | .134 |

Note. N = 68. $df_{error}$ = 65

Table H.45

*TD: Results of pairwise-comparisons in the task AMBSENT*

| | | | | | | $M_{diff}$ | *p* | *Direction of difference* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Reaction Time* | *Facilitation Condition* | context | bias | vs | neu | -130 | <.001 | bias | < | neu |
| | | dominance | dom | vs | sub | -149 | <.001 | dom | < | sub |
| | | age group | child | vs | adole | 534 | <.001 | child | > | adole |
| | | | child | vs | adult | 509 | <.001 | child | > | adult |
| | | | adole | vs | adult | -25 | 1 | adole | = | adult |
| | *CFR* | dominance | dom | vs | sub | -0.06 | .048 | dom | < | sub |
| | *Suppression Condition* | ambiguity | unamb | vs | amb | -74 | .003 | unamb | < | amb |
| | | dominance | dom | vs | sub | 97 | <.001 | dom | > | sub |
| | | age group | child | vs | adole | 648 | <.001 | child | > | adole |
| | | | child | vs | adult | 658 | <.001 | child | > | adult |
| | | | adole | vs | adult | 10 | 1 | adole | = | adult |
| | | ambiguity * dominance | | | | | | | | |
| | | amb: | dom | vs | sub | 77 | .001 | dom | > | sub |
| | | unamb: | dom | vs | sub | 114 | <.001 | dom | > | sub |
| | | dom: | amb | vs | unamb | 53 | .388 | amb | = | unamb |
| | | sub: | amb | vs | unamb | 90 | <.001 | amb | > | unamb |
| | CSR | dominance | dom | vs | sub | 0.05 | .014 | dom | > | sub |
| *Accuracy* | *Facilitation Condition* | context | bias | vs | neu | 5.1 | <.001 | bias | > | neu |
| | | dominance | dom | vs | sub | 7.9 | <.001 | dom | > | sub |
| | | age group | child | vs | adole | -8.4 | <.001 | child | < | adole |
| | | | child | vs | adult | -11.2 | <.001 | child | < | adult |
| | | | adole | vs | adult | -2.8 | .243 | adole | = | adult |
| | | context * dominance * age group | | | | | | | | |
| | | biased | | | | | | | | |
| | | child | dom | vs | sub | 6.3 | .002 | dom | > | sub |
| | | adole | dom | vs | sub | 2.1 | .199 | dom | = | sub |
| | | adult | dom | vs | sub | -0.2 | .796 | dom | = | sub |
| | | neutral | | | | | | | | |
| | | child | dom | vs | sub | 24.5 | <.001 | dom | > | sub |
| | | adole | dom | vs | sub | 9.3 | <.001 | dom | > | sub |
| | | adult | dom | vs | sub | 5.4 | .006 | dom | > | sub |
| | *CFR* | dominance | dom | vs | sub | -0.18 | <.001 | dom | < | sub |
| | | dominance * age group | | | | | | | | |
| | | dom | child | vs | adole | 0.0 | 1 | child | = | adole |
| | | | child | vs | adult | -2.00 | 1 | child | = | adult |
| | | | adole | vs | adult | 0.01 | 1 | adole | = | adult |
| | | sub | child | vs | adole | 0.29 | .01 | child | > | adole |
| | | | child | vs | adult | 0.31 | .005 | child | > | adult |
| | | | adole | vs | adult | 0.02 | 1 | adole | = | adult |
| | *Suppression Condition* | ambiguity * dominance | | | | | | | | |
| | | amb: | dom | vs | sub | 3.1 | .035 | dom | = | sub |
| | | unamb: | dom | vs | sub | -1.7 | .003 | dom | < | sub |
| | | dom: | amb | vs | unamb | -10.3 | <.001 | amb | < | unamb |
| | | sub: | amb | vs | unamb | -15.2 | <.001 | amb | < | unamb |
| | | age group | child | vs | adole | -6.5 | .02 | child | < | adole |
| | | | child | vs | adult | -8.7 | .001 | child | < | adult |
| | | | adole | vs | adult | -2.2 | 1 | adole | = | adult |
| | *CSR* | dominance | dom | vs | sub | 0.05 | .004 | dom | > | sub |
| | | age group | child | vs | adole | -0.08 | .128 | child | = | adole |
| | | | child | vs | adult | -0.13 | .008 | child | < | adult |
| | | | adole | vs | adult | -0.04 | .864 | adole | = | adult |

*Note.* Alpha level $\alpha = .05$ (with adjusted p-values for multiple comparisons) if not otherwise specified.

Abbreviations: $M_{diff}$ = mean difference, bias = biased, neu = neutral, dom = dominant, sub = subordinate, adole = adolescent, unamb = unambiguous, amb = ambiguous

Table H.46

*ASD vs AmTD: ANOVA Results in the task AMBSENT for DVs: RT and ACC*

| | | DV: Reaction Time | | | DV: Accuracy | | |
|---|---|---|---|---|---|---|---|
| | *df* | *F* | *p* | $\eta^2$ | *F* | *p* | $\eta^2$ |
| *Facilitation condition* | | | | | | | |
| context | 1 | 77.521 | <.001 | .466 | 20.175 | <.001 | .185 |
| context * age group | 2 | 3.530 | .033 | .073 | .454 | .637 | .010 |
| context * sample group | 1 | .553 | .459 | .006 | .281 | .597 | .003 |
| context * age group * sample group | 2 | 2.056 | .134 | .044 | .148 | .862 | .003 |
| dominance | 1 | 143.411 | <.001 | .617 | 58.020 | <.001 | .395 |
| dominance * age group | 2 | 1.686 | .191 | .037 | 6.370 | .003 | .125 |
| dominance * sample group | 1 | 2.364 | .128 | .026 | 2.456 | .121 | .027 |
| dominance * age group * sample group | 2 | 2.460 | .091 | .052 | 4.147 | .019 | .085 |
| context * dominance | 1 | 2.142 | .147 | .023 | 34.976 | <.001 | .282 |
| context * dominance * age group | 2 | 1.600 | .208 | .035 | 1.478 | .234 | .032 |
| context * dominance * sample group | 1 | .164 | .686 | .002 | 3.220 | .076 | .035 |
| context * dominance * age group * sample group | 2 | 1.075 | .346 | .024 | 5.494 | .006 | .110 |
| age group | 2 | 21.627 | <.001 | .327 | 5.730 | .005 | .114 |
| sample group | 1 | 8.954 | .004 | .091 | .018 | .893 | <.001 |
| age group * sample group | 2 | .105 | .900 | .002 | 2.507 | .087 | .053 |
| *Supression condition* | | | | | | | |
| ambiguity | 1 | 10.708 | .002 | .108 | 66.954 | <.001 | .429 |
| ambiguity * age group | 2 | 2.130 | .125 | .046 | 5.252 | .007 | .106 |
| ambiguity * sample group | 1 | .542 | .464 | .006 | .455 | .502 | .005 |
| ambiguity * age group * sample group | 2 | .670 | .514 | .015 | 1.009 | .369 | .022 |
| dominance | 1 | 62.279 | <.001 | .414 | 1.064 | .305 | .012 |
| dominance * age group | 2 | 2.113 | .127 | .046 | 2.551 | .084 | .054 |
| dominance * sample group | 1 | .023 | .879 | <.001 | 1.735 | .191 | .019 |
| dominance * age group * sample group | 2 | .719 | .490 | .016 | .530 | .591 | .012 |
| ambiguity * dominance | 1 | 13.693 | <.001 | .135 | 17.898 | <.001 | .167 |
| ambiguity * dominance * age group | 2 | .517 | .598 | .012 | 3.096 | .050 | .065 |
| ambiguity * dominance * sample group | 1 | <.001 | .998 | <.001 | 2.925 | .091 | .032 |
| ambiguity * dominance * age group * sample group | 2 | .518 | .598 | .012 | 2.084 | .130 | .045 |
| age group | 2 | 31.778 | <.001 | .419 | 9.189 | <.001 | .171 |
| sample group | 1 | 8.336 | .005 | .087 | 1.909 | .171 | .021 |
| age group * sample group | 2 | .108 | .898 | .002 | 1.642 | .199 | .036 |

*Note*. N = 95. dferror = 89. Analysis methods: 2x3x2x2 repeated measures ANOVAs in the contextual facilitation (factors: context type, dominance, age group, sample group) and suppression conditions (factors: ambiguity, dominance, age group, sample group)

Table H.47

*ASD vs AmTD: ANOVA Results in the task AMBSENT for DVs: CFR, CSR, TFR and TIS for RT and ACC*

| | | | Reaction Time | | | Accuracy | | |
|---|---|---|---|---|---|---|---|---|
| | | *df* | *F* | *p* | *η2* | *F* | *p* | *η2* |
| *Facilitation Condition* | | | | | | | | |
| DV: CFR | dominance | 1 | 2.727 | .102 | .030 | 27.419 | <.001 | .236 |
| | dominance * age group | 2 | 1.716 | .186 | .037 | 2.630 | .078 | .056 |
| | dominance * sample group | 1 | .027 | .869 | <.001 | 2.698 | .104 | .029 |
| | dominance * age group * sample group | 2 | .776 | .463 | .017 | 6.344 | .003 | .125 |
| | age group | 2 | 1.798 | .172 | .039 | 1.095 | .339 | .024 |
| | sample group | 1 | .224 | .637 | .003 | .018 | .893 | <.001 |
| | age group * sample group | 2 | 2.369 | .099 | .051 | 1.343 | .266 | .029 |
| DV: TFS | age group | 2 | 1.150 | .321 | .025 | .454 | .637 | .010 |
| | sample group | 1 | .001 | .972 | <.001 | .281 | .597 | .003 |
| | age group * sample group | 2 | 1.062 | .350 | .023 | .148 | .862 | .003 |
| *Suppression Condition* | | | | | | | | |
| *DV: CSR* | dominance | 1 | 13.606 | <.001 | .134 | 17.569 | <.001 | .165 |
| | dominance * age group | 2 | 1.216 | .301 | .027 | 3.537 | .033 | .074 |
| | dominance * sample group | 1 | .036 | .849 | <.001 | 3.065 | .083 | .033 |
| | dominance * age group * sample group | 2 | .273 | .762 | .006 | 2.223 | .114 | .048 |
| | age group | 2 | 2.058 | .134 | .045 | 5.969 | .004 | .118 |
| | sample group | 1 | .138 | .711 | .002 | .992 | .322 | .011 |
| | age group * sample group | 2 | .743 | .479 | .017 | 1.244 | .293 | .027 |
| DV: TIS | age group | 2 | 2.053 | .134 | .045 | 6.029 | .004 | .119 |
| | sample group | 1 | .362 | .549 | .004 | 1.069 | .304 | .012 |
| | age group * sample group | 2 | .985 | .377 | .022 | 1.264 | .288 | .028 |

## H.3. SENTORD

### H.3.1. Descriptive Statistics

Table H.48

*Descriptive Statistics for TD and ASD in SENTORD*

| | | | Child | | Adolescent | | Adult | | Overall | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| TD | | | | | | | | | | |
| | RT (sec) | coherence | 16.28 | 7.75 | 10.39 | 4.21 | 14.63 | 8.17 | 13.7 | 7.3 |
| | | temporal | 17.27 | 6.42 | 10.22 | 3.45 | 14.63 | 7.15 | 13.95 | 6.5 |
| | ACC | coherence | 60.7% | 17.4% | 73.9% | 16.4% | 75.0% | 13.8% | 70.2% | 16.9% |
| | | temporal | 64.9% | 16.6% | 78.8% | 18.6% | 88.5% | 14.2% | 78.0% | 19.0% |
| | TempFR | RT | -0.99 | 7.26 | 0.17 | 2.63 | 0 | 3.54 | -0.25 | 4.75 |
| | | ACC | 0.05 | 0.17 | 1.09 | 0.18 | 0.14 | 0.2 | 0.08 | 0.19 |
| ASD | | | | | | | | | | |
| | RT (sec) | coherence | 24.57 | 10.23 | 18.45 | 10.78 | 17.29 | 8.97 | 19.35 | 10.15 |
| | | temporal | 23.87 | 8.03 | 18.36 | 10.42 | 17.32 | 9.85 | 19.18 | 9.85 |
| | ACC | coherence | 43.8% | 23.5% | 70.8% | 18.2% | 68.1% | 17.9% | 63.3% | 22.1% |
| | | temporal | 42.7% | 29.9% | 76.4% | 19.6% | 81.3% | 16.5% | 70.3% | 26.2% |
| | TempFR | RT | 0.64 | 4.24 | 0.09 | 4.64 | -0.03 | 5.54 | 0.17 | 4.85 |
| | | ACC | -0.01 | 0.25 | 0.06 | 0.20 | 0.13 | 0.18 | 0.07 | 0.21 |

## H.3.2. Inferential Statistics

Table H.49

*TD: ANOVA results for the task SENTORD*

| | | *df (factor, error)* | *F* | *p* | $\eta^2$ |
|---|---|---|---|---|---|
| *Reaction Time (correct responses)* | | | | | |
| | condition | 1, 65 | 0.773 | .383 | .012 |
| | age group | 2, 65 | 7.544 | .001 | .188 |
| | condition * age group | 2, 65 | 0.472 | .626 | .014 |
| *Reaction Time (all responses)* | | | | | |
| | condition | 1, 65 | 3.200 | .078 | .047 |
| | age group | 2, 65 | 8.141 | .001 | .200 |
| | condition * age group | 2, 65 | 0.714 | .494 | .021 |
| *Accuracy* | | | | | |
| | condition | 1, 65 | 11.272 | .001 | .148 |
| | age group | 1, 65 | 11.892 | <.001 | .268 |
| | condition * age group | 2, 65 | 1.850 | .165 | .054 |
| *TFRcorrect* | | | | | |
| | age group | 2, 65 | 0.124 | .883 | .004 |
| *TFRacc* | | | | | |
| | age group | 2, 65 | 1.126 | .331 | .033 |

Table H.50

*TD: Results of post-hoc tests/ pairwise comparisons for the task SENTORD*

| | | | | | mean difference | *p* | *Direction of Difference* | | |
|---|---|---|---|---|---|---|---|---|---|
| *RT (correct)* | age group | child | vs | adole | 6.46 | .001 | child | > | adole |
| | | child | vs | adult | 2.15 | .490 | child | = | adult |
| | | adole | vs | adult | -4.32 | .044 | adole | < | adult |
| RT (all) | age group | child | vs | adole | 7.58 | <.001 | child | > | adole |
| | | child | vs | adult | 3.98 | .108 | child | = | adult |
| | | adole | vs | adult | -3.61 | .155 | adole | > | adult |
| Accuracy | condition | coherence | vs | temporal | -7.50 | .001 | coherence | < | temporal |
| | age group | child | vs | adole | -13.6 | .004 | child | < | adole |
| | | child | vs | adult | -19.0 | <.001 | child | < | adult |
| | | adole | vs | adult | -5.4 | .504 | adole | = | adult |
| TFR | child | $TFR_{RT}$ | vs | 1 | -0.02 | .829 | $TFR_{RT}$ | = | 1 |
| | | TFRacc | vs | 1 | 0.12 | .088 | TFRacc | = | 1 |
| | adole | $TFR_{RT}$ | vs | 1 | -0.06 | .305 | $TFR_{RT}$ | = | 1 |
| | | TFRacc | vs | 1 | 0.09 | .161 | TFRacc | = | 1 |
| | adult | $TFR_{RT}$ | vs | 1 | 0.02 | .704 | $TFR_{RT}$ | = | 1 |
| | | TFRacc | vs | 1 | 0.22 | .002 | TFRacc | > | 1 |

Table H.51

*ASD vs AmTD: ANOVA results for the task SENTORD*

| | *df* | *F* | *p* | $\eta^2$ |
|---|---|---|---|---|
| *Reaction Time (correct responses)* | | | | |
| condition | 1 | .037 | .849 | <.001 |
| condition * age group | 2 | .383 | .683 | .009 |
| condition * sample group | 1 | .051 | .822 | .001 |
| condition * age group * sample group | 2 | .042 | .959 | .001 |
| age group | 2 | 5.734 | .005 | .115 |
| sample group | 1 | 10.420 | .002 | .106 |
| age group * sample group | 2 | 1.235 | .296 | .027 |
| *Accuracy* | | | | |
| condition | 1 | 8.932 | .004 | .091 |
| condition * age group | 2 | 2.951 | .057 | .062 |
| condition * sample group | 1 | .002 | .966 | <.001 |
| condition * age group * sample group | 2 | .098 | .907 | .002 |
| age group | 2 | 20.841 | <.001 | .319 |
| sample group | 1 | 16.419 | <.001 | .156 |
| age group * sample group | 2 | 2.577 | .082 | .055 |
| *TFRcorrect* | | | | |
| age group | 2 | .216 | .806 | .005 |
| sample group | 1 | .010 | .920 | <.001 |
| age group * sample group | 2 | .031 | .970 | .001 |
| *TFRacc* | | | | |
| age group | 2 | 1.860 | .162 | .041 |
| sample group | 1 | .401 | .528 | .005 |
| age group * sample group | 2 | .176 | .839 | .004 |

## H.4. SENTCOMP

### H.4.1. Descriptive Statistics

Table H.52

*Descriptive results for current ASD and TD samples and for those of Booth & Happe (2010) for Completion Scores, Number of Local Completions and Response Times (sec) in SENTCOMP*

| Sample Group | Age group | N | Range | | M | SD |
|---|---|---|---|---|---|---|
| Completion Score (max = 20) | | | | | | |
| Current ASD | Child (8-10) | 11 | 8 | 19 | 15.09 | 3.48 |
| | Adolescent (11-17) | 18 | 8 | 20 | 16.00 | 3.14 |
| | Adult (18+) | 14 | 12 | 20 | 17.50 | 2.44 |
| Booth & Happe ASD | Child M(SD = 11(2.5) yrs | 30 | 7 | 20 | 14.98 | 3.79 |
| | Adolescent M(SD) = 14.4(2.6) yrs | 41 | 8 | 20 | 15.63 | 2.80 |
| | Adult | N/A | N/A | N/A | N/A | N/A |
| Current TD | Child (8-10) | 3 | 12 | 19 | 16.33 | 3.79 |
| | Adolescent (11-17) | 3 | 15 | 20 | 18.33 | 2.89 |
| | Adult (18+) | 10 | 12 | 20 | 18.50 | 2.37 |
| Booth & Happe TD | Child 8-10) | 47 | 8 | 20 | 17.47 | 2.28 |
| | Child (11-13) | 40 | 10 | 20 | 17.38 | 2.56 |
| | Adolescent (14-16) | 44 | 10 | 20 | 18.52 | 2.18 |
| | Adult (17-25) | 45 | 13 | 20 | 18.51 | 1.63 |
| Local Completions (max = 10) | | | | | | |
| Current ASD | Child (8-10) | 11 | 0 | 4 | 1.64 | 1.50 |
| | Adolescent (11-17) | 18 | 0 | 6 | 1.44 | 1.50 |
| | Adult (18+) | 14 | 0 | 4 | 0.50 | 1.09 |
| Booth & Happe ASD | Child M(SD = 11(2.5) yrs | 30 | 0 | 6 | 1.77 | 1.72 |
| | Adolescent M(SD) = 14.4(2.6) yrs | 41 | 0 | 5 | 1.56 | 1.38 |
| | Adult | N/A | N/A | N/A | N/A | N/A |
| Current TD | Child (8-10) | 3 | 0 | 3 | 1.00 | 1.73 |
| | Adolescent (11-17) | 3 | 0 | 2 | 0.67 | 1.15 |
| | Adult (18+) | 10 | 0 | 3 | 0.40 | 0.97 |
| Booth & Happe TD | Child 8-10) | 47 | 0 | 6 | 0.74 | 1.11 |
| | Child (11-13) | 40 | 0 | 5 | 0.90 | 1.28 |
| | Adolescent (14-16) | 44 | 0 | 5 | 0.59 | 1.06 |
| | Adult (17-25) | 45 | 0 | 2 | 0.44 | 0.69 |
| Response Time (RT) (max = 21 sec) | | | | | | |
| Current ASD | Child (8-10) | 11 | 2 | 11 | 5.20 | 2.53 |
| | Adolescent (11-17) | 18 | 2 | 9 | 3.63 | 2.20 |
| | Adult (18+) | 14 | 1 | 10 | 4.00 | 2.87 |
| Booth & Happe ASD | Child M(SD = 11(2.5) yrs | 30 | 1 | 11 | 3.79 | 2.03 |
| | Adolescent M(SD) = 14.4(2.6) yrs | 41 | 1 | 10 | 3.54 | 2.17 |
| | Adult | N/A | N/A | N/A | N/A | N/A |
| Current TD | Child (8-10) | 3 | 5 | 6 | 5.12 | 0.43 |
| | Adolescent (11-17) | 3 | 2 | 3 | 2.37 | 0.56 |
| | Adult (18+) | 10 | 1 | 6 | 3.45 | 1.68 |
| Booth & Happe TD | Child 8-10) | 47 | 1 | 12 | 3.91 | 1.87 |
| | Child (11-13) | 40 | 1 | 10 | 3.12 | 1.72 |
| | Adolescent (14-16) | 44 | 1 | 4 | 1.89 | 0.74 |
| | Adult (17-25) | 45 | 1 | 10 | 2.56 | 1.60 |

*Note.* Range: minimum and maximum scores.

# Appendix I Correlation Matrix for Chapter 10

Table I.53

*Matrix of the correlations between selected language and visual measures for all participants (ASD+TD)*

| | | | Vocabulary | AQ | AMBWORD | SENTORD temporal | visual task (G80L20) | AMBSENT | SENTORD coherence | SENTCOMP |
|---|---|---|---|---|---|---|---|---|---|---|
| Local | visual task (G20L80) | $r$ | .12 | -.04 | .04 | .05 | -.11 | .08 | .17~ | .29* |
| | | $pr_{age}$ | .12 | -.04 | .05 | .06 | -.11 | .08 | .17~ | .30* |
| | | $pr_{VP}$ | | -.03 | .06 | .02 | -.11 | .08 | .14 | .28* |
| | | $pr_{age\ \&\ VP}$ | | -.03 | .06 | .02 | -.11 | .09 | .14 | .29* |
| | | $pr_{AQ}$ | .12 | | .05 | .05 | -.11 | .08 | .17~ | .30* |
| | | $pr_{age\ \&\ AQ}$ | .12 | | .05 | .05 | -.11 | .08 | .17~ | .31* |
| | | $pr_{age\ \&\ VP\ \&\ AQ}$ | | | .06 | .01 | -.11 | .08 | .14 | .30* |
| | AMBWORD accuracy | $r$ | -.11 | .07 | | .46*** | -.14 | .46*** | .44*** | .26* |
| | | $pr_{age}$ | -.07 | -.04 | | .39*** | -.12 | .41*** | .42*** | .22 |
| | | $pr_{VP}$ | | .07 | | .51*** | -.14 | .46*** | .51*** | .27* |
| | | $pr_{age\ \&\ VP}$ | | -.04 | | .44*** | -.12 | .47*** | .47*** | .27~ |
| | | $pr_{AQ}$ | -.11 | | | .48*** | -.15 | .47*** | .46*** | .30* |
| | | $pr_{age\ \&\ AQ}$ | -.07 | | | .40*** | -.12 | .41*** | .42*** | .22~ |
| | | $pr_{age\ \&\ VP\ \&\ AQ}$ | | | | .45*** | -.12 | .41*** | .47*** | .23~ |
| | SENTORD temporal accuracy | $r$ | .27** | -.14 | | | -.04 | .25** | .58*** | .31* |
| | | $pr_{age}$ | .34*** | -.26 | | | -.01 | .18 | .56*** | .28* |
| | | $pr_{VP}$ | | -.12 | | | -.06 | .28** | .54*** | .30* |
| | | $pr_{age\ \&\ VP}$ | | -.26** | | | -.03 | .20* | .51*** | .26~ |
| | | $pr_{AQ}$ | .27** | | | | -.04 | .25** | .58*** | .28* |
| | | $pr_{age\ \&\ AQ}$ | .34*** | | | | .00 | .16 | .55*** | .19 |
| | | $pr_{age\ \&\ VP\ \&\ AQ}$ | | | | | -.02 | .18~ | .49*** | .17 |
| Global | visual task (G80L20) | $r$ | .05 | .02 | | | | -.06 | -.01 | -.13 |
| | | $pr_{age}$ | .04 | .05 | | | | -.04 | .00 | -.11 |
| | | $pr_{VP}$ | | .03 | | | | -.06 | -.03 | -.13 |
| | | $pr_{age\ \&\ VP}$ | | .05 | | | | -.04 | -.01 | -.12 |
| | | $pr_{AQ}$ | .05 | | | | | -.06 | -.01 | -.13 |
| | | $pr_{age\ \&\ AQ}$ | .04 | | | | | -.04 | .01 | -.10 |
| | | $pr_{age\ \&\ VP\ \&\ AQ}$ | | | | | | -.03 | .00 | -.10 |
| | AMBSENT $CSR_{ACC}$ subordinate | $r$ | -.05 | -.02 | | | | | .19* | .06 |
| | | $pr_{age}$ | -.02 | -.11 | | | | | .15 | .01 |
| | | $pr_{VP}$ | | -.02 | | | | | .22* | .06 |
| | | $pr_{age\ \&\ VP}$ | | -.11 | | | | | .17~ | .02 |
| | | $pr_{AQ}$ | -.05 | | | | | | .19* | .05 |
| | | $pr_{age\ \&\ AQ}$ | -.02 | | | | | | .14 | -.03 |
| | | $pr_{age\ \&\ VP\ \&\ AQ}$ | | | | | | | .15 | -.03 |
| | SENTORD coherence accuracy | $r$ | .31*** | -.11 | | | | | | .21 |
| | | $pr_{age}$ | .35*** | -.17~ | | | | | | .19 |
| | | $pr_{VP}$ | | -.08 | | | | | | .20 |
| | | $pr_{age\ \&\ VP}$ | | -.16 | | | | | | .17 |
| | | $pr_{AQ}$ | .31*** | | | | | | | .19 |
| | | $pr_{age\ \&\ AQ}$ | .34*** | | | | | | | .14 |
| | | $pr_{age\ \&\ VP\ \&\ AQ}$ | | | | | | | | .11 |
| | SENTCOMP completion score | $r$ | .08 | -.34** | | | | | | |
| | | $pr_{age}$ | .10 | -.41** | | | | | | |
| | | $pr_{VP}$ | | -.34** | | | | | | |
| | | $pr_{age\ \&\ VP}$ | | -.41** | | | | | | |
| | | $pr_{AQ}$ | .06 | | | | | | | |
| | | $pr_{age\ \&\ AQ}$ | .09 | | | | | | | |
| | | $pr_{age\ \&\ VP\ \&\ AQ}$ | | | | | | | | |

*Note.* ~$p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$. The accepted α-level was α = .01 in order to correct for multiple comparisons.

# Appendix J Published Works

Note, the authors surname was formally changed from Wohlrapp to Smith in 2014

## J.1. Published Articles

Vulchanova, M., Chahboun, S., Wohlrapp, D., Gudde, H., Voss, F. (2014). The Traps of communication. Pan European Networks: Science & Technology, 12, p. 28-29.

## J.2. Conference Abstracts

### J.2.1.1. Poster Presentations

**Wohlrapp, D., Vulchanova, M., Talcott, J. (2013). The Development of Local and Global Processing: From Perception to Language. Poster presentation at the Cognition and Language in Developmental Disorders Workshop, Seville, Spain.**

Background: The Weak Central Coherence account is one theory explaining the underlying mechanisms of Autistic Spectrum Disorder (ASD). Central Coherence describes the tendency to process information in its given context. Many experiences can only be understood by combining separate *local* information to a coherent *global* whole. Individuals with ASD seem to exhibit a bias towards local processing: in the domain of vision they tend to see separate items but not the overall form; in audition they perceive direction of pitch changes but not direction of pitch contour; in language they master lexicon and grammar but not metaphors. To date, there is no consent about the relationship of local and global processing across different domains and how they are represented in ASD.

Objectives: By means of a three groups design we aim to examine local and global perception across domains, analyse the neural correlates of the different processing levels, and to clarify whether the processing framework reflects a developmental delay or atypical trajectory. An intervention study could inform possible treatment for improving global perception in ASD.

Project Outline**:** Tests will assess the auditory, visual and language domain. A pilot study will be conducted for testing the design and choosing tasks showing best discriminability of processing levels. Selected tests will be applied on a larger cross-sectional sample of healthy participants. Performance will be compared across modalities and an individual global-to-local performance ratio will be calculated resulting in ratio record for different age groups and modalities. Next, individuals with ASD will be tested on the tasks while undergoing a MEG in order to examine the neural correlates of local and global processing in Autism. Their performance will be compared to the healthy individuals. Finally, a number of individuals in each group will undergo an intervention aiming to shift the global to local ratio.

**Wohlrapp, D., Vulchanova, M., Talcott, J. (2014). I spy with my little eye – Implicit Learning in Local and Global Perception. Poster presentation at the LHS Research Day at Aston University, Birmingham, UK.**

Local and global perception in typical and atypical development have been assessed in a large number of studies which led to the view that typically developed individuals show a bias towards global processing, and atypically developed individuals e.g. with Autism, exhibit a bias towards local processing. However, as an increasing amount of findings are inconsistent with those original assumptions, our aim is to explore factors that are associated with enhanced global or local processing. In this study, effects on local and global processing from possible moderators like age or mood will be explored in typical development. Understanding more about factors that influence local and global processing in typical development could give insight into processing styles also in atypical development. A cross-sectional sample of healthy participants aged 7-65 will be assessed on visual and auditory tasks assessing local and global perception. Associations between task performance and age, homograph reading, performance/verbal IQ, autistic traits as well as mood will be explored. Based on previous research, we expect to find increased local processing in participants with younger age, higher performance IQ, higher scores of autistic traits, and lower mood scores. Global processing is expected to be associated with older age, higher verbal IQ, less autistic traits, and better mood.

**Wohlrapp, D., Vulchanova, M., Talcott, J. (2014). I spy with my little eye – Local & Global Processing in Perception & Language. Poster presentation at ESLP Conference, Rotterdam, Netherlands.**

Background: Local and global perception in typical and atypical development have been assessed in a large number of studies which led to the view that typically developed individuals show a bias towards global processing, and atypically developed indiduals e.g. with Autism, exhibit a bias towards local processing. However, as an increasing amount of findings are inconsistent with those original assumptions, our aim is to explore factors that are associated with enhanced global or local processing. In this study, effects on local and global processing from possible moderators like language abilities or age will be explored in typical development. Understanding more about factors that influence local and global processing in typical development could give insight into processing styles also in atypical development.

Methods: A cross-sectional sample of healthy participants aged 7-65 will be assessed on visual and auditory tasks assessing local and global perception. Associations between task performance and age, homograph reading, performance/verbal IQ, autistic traits as well as mood will be explored.

Hypotheses: Based on previous research, we expect to find increased local processing in participants with younger age, higher performance IQ, higher scores of autistic traits, and lower mood scores. Global processing is expected to be associated with older age, higher verbal IQ, less autistic traits, and better mood.

**Smith, D., Vulchanova, M., Talcott, J. (2015). Local and Global Processing in Typical Development: Perceptual and Strategic Aspects. Poster presentation at the Annual Conference of the West Midlands Branch of BPS, Coventry, UK.**

Purpose: Local and global processing in visual perception has been assessed in a large number of studies which led to the view that typically developing (TD) individuals show a bias towards global processing, and atypically developing individuals e.g. with Autism, exhibit a bias towards local processing. However, as an increasing amount of findings are inconsistent with those original assumptions, our aim is to explore factors that are associated with enhanced global or local processing.

Methods: In total, 48 TD participants aged 19-38 completed a range of experiments assessing local and global processing in visual perception. In experiment 1 we used stimuli that varied across several perceptual dimensions (size, number of elements, form) examining the influence of stimulus characteristics on the global precedence effect. Experiment 2 involved manipulations of contingencies of local and global targets and examined the flexibility of the global precedence. Experiment 3 was based on experiment 2 but additionally included a masking stimulus that intended to interrupt stimulus processing on the perceptual level.

Results: In experiment 1 we showed that the global precedence effect is mainly independent of perceptual stimulus characteristics. Experiment 2 revealed that participants can modulate their processing and switch from a global to local bias if this is strategically favourable. Masking significantly impaired local processing in experiment 3.

Conclusions: The global precedence effect has perceptual and strategic aspects. It appears to be mandatory on the perceptual stage (experiment 1 and 2) but can be altered strategically during the decision stage (experiment 2 and 3).

**Smith, D., Vulchanova, M., Talcott, J. (2015). Local and Global Processing in Perception and Language in Children and Adults. Poster presentation at the Annual Conference of the Developmental and Social Sections of BPS, Manchester, UK.**

Background: Local and global processing can be examined in different domains: While processing styles in visual perception have long been in the centre of attention, in language they remain underexamined. In vision, local features are details, whereas the 'big picture' is the global aspect; In language local refers to single words or simple grammar and global processing to using context and being able to make inferences. To our knowledge, processing styles have not yet been examined in these two domains within the same participants. Further, the developmental aspect of local and global processing in perception and language is yet to be clarified. We are reporting first results gained from a cross-sectional sample with participants aged 8-30 years.

Methods: Visual tasks involved hierarchical figures with geometrical forms, manipulation of contingencies of local and global trials, and backward-masking versus no masking. Language tasks included ambiguous words and sentences and a sentence ordering task. All tasks required local or global processing for successful completion.

Findings: In adults a global perception bias was found which could be adjusted depending on the contingency of local and global trials. Masking significantly impaired accuracy in local but not global trials. These effects were less pronounced in young children. All groups showed context facilitation in language tasks. Children were less efficient in activating subordinate meanings and using context information.

Discussion: Preliminary data confirms global processing abilities develop and increase in typically developing individuals with age. Although adults have a global perception bias, it can be adjusted voluntarily.

### J.2.1.2. Conference Talks

**Smith, D., Vulchanova, M., Talcott, J. (2016). Local and Global Processing in Language and Visual Perception in Typical and Atypical Development. Oral Presentation at the Language and Perception International Conference, Trondheim, Norway.**

Background

Local (detailed) and global (holistic) processing has been a topic of research interest for many decades. However, certain questions are still insufficiently answered. Where do perception biases stem from? How does local/global processing develop? What goes 'wrong' in atypical development, such as in Autism? How is local/global processing in different modalities like language and vision connected? This research project aimed to address those questions.

Method

Study 1: 3 experiments (N = 47) explored effects of stimulus and task characteristics on local/global processing in vision using hierarchical figures. Study 2: 60 participants aged 7-40 completed a battery of local/global language and visual perception tasks including ambiguous words/sentences, sentence completion, sentence ordering, hierarchical figures, verbal/non-verbal performance. Study 3: 17 participants with ASD aged 8-53 completed the same test battery.

Results

Preliminary analyses suggest: In visual processing the mandatory perceptual global bias can flexibly be overcome depending on task characteristics. This bias is present already in children. Participants with ASD have less global but no local bias. In language processing children are activating subordinate meanings of ambiguous words less effectively than adolescents/adults even given biasing context. ASD adults are less affected by meaning dominance in ambiguous words and sentences than control participants.

**Smith, D., Vulchanova, M., Talcott, J. (2016). Visual Processing in ASD – How Mario saw the trees but missed the forest. Oral Presentation at the LHD Postgraduate Research Day, Aston University, Birmingham, UK.**

Purpose: Local (detailed) and global (holistic) processing has been a topic of research interest for many decades. However, questions still remain, e.g. how processing biases develop in typical versus atypical development, such as Autism Spectrum Disorders (ASD) and how flexible biases are. This study examined processing biases comparing children, adolescents and adults with and without a diagnosis of ASD. It was expected to find a local/no bias in typically developing (TD) children that developed into a global bias in adults, and a local bias in ASD children, adolescents and adults.

Method: 60 TD participants aged 7-40 and 20 participants with ASD aged 8-53 completed 5 blocks of a hierarchical stimulus paradigm (big 'global' forms made out of small 'local' forms) with targets on either the global or local level. We examined a) local/global perception biases, b) the flexibility of the bias (using blocks with varying percentages of local/global targets).

Results: In the TD group a global bias was found across age groups. In ASD, no bias was found in children but an increasing global bias in adolescents and adults. Biases were flexible in both groups and could be pushed towards more local or more global by means of contingencies.

Discussion: The findings in the ASD group corresponded more to the expected 'typically developing' trajectory than those of the control group. Potentially, the global bias develops even earlier in TD children, indicating a developmental delay in ASD.

**Smith, D., Vulchanova, M., Talcott, J. (2016). Local and global processing in ASD revisited: models, mechanisms and caveats. Oral Presentation at Annual Conference of the Developmental and Social Sections of BPS, Belfast, UK.**

Background: Local (detailed) and global (holistic) processing has been a topic of research interest for many decades. However, questions still remain, e.g. how processing biases develop in typical versus atypical development, such as Autism Spectrum Disorders (ASD) and how flexible biases are. This study examined processing biases comparing children, adolescents and adults with and without a diagnosis of ASD. It was expected to find a local/no bias in typically developing (TD) children that developed into a global bias in adults, and a local bias in ASD children, adolescents and adults.

Method: 60 TD participants aged 7-40 and 20 participants with ASD aged 8-53 completed 5 blocks of a hierarchical stimulus paradigm (big 'global' forms made out of small 'local' forms) with targets on either the global or local level. We examined a) local/global perception biases, b) the flexibility of the bias (using blocks with varying percentages of local/global targets), c) the influence of stimulus duration.

Results: In the TD group a global bias was found across age groups. In ASD, no bias was found in children but an increasing global bias in adolescents and adults. Biases were flexible in both groups and could be pushed towards more local or more global by means of contingencies. Stimulus durations had no level-specific impact.