THE ROLE OF OVER AND UNDER ACTIVATION IN THE EMERGENCE OF SPOKEN LANGUAGE DEFICITS

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In the current thesis, I advance the idea that semantic interference and semantic errors are bound to occur in healthy individual as an effect of experimental conditions and especially when language areas of the brain are compromised following a brain injury. My thesis program can be described as a series of steps, in which I tested different models of lexical retrieval by means of specific methods on both healthy and aphasic population.

The *first step* investigated the extent to which the amount of semantic interference may be modulated by individual predisposition towards the perception of part of a context as discrete from the surrounding field: field dependent and field independent cognitive styles. I found a relationship between semantic interference in naming and cognitive styles.

The *second step* aimed to gather evidence about the long-lasting effect of cumulative semantic interference. By providing two alternative versions of the continuous picture naming task, I explored, respectively: a) the extent to which the increasing of semantic interference accrues over the ordinal positions described in the literature; b) whether semantic interference decayed after an amount of time. I found that the activation of a target representation dissipates after an unfilled delay and that the strength of interference tapers off after presentation of distractors.

The *third step* aimed to disentangle the contribution of bottom-up and top-down mechanisms in the emergence of lexical deficits in a population of aphasic patients. I compared the performance of aphasic patients and healthy individuals in naming tasks inducing semantic interference, in a short-term memory task and, finally, in a Stroop task. Our patients showed two distinct patterns consistent with a damage to activation vs inhibition mechanisms.

In conclusion, semantic interference and semantic errors offer an important view to a better understanding of the cognitive mechanisms underpin normal and pathological word retrieval.

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Chapter 1: General Introduction

Language production relies on different cognitive processes chief among them lexical retrieval. This process reflects the selection of a target word, as per the intended message of the speaker. Lexical retrieval has been conceived as a multi-staged process, namely the access to semantic knowledge, the activation of the spoken form of the word in the phonological output lexicon. Finally, the engagement of the correct motor program required to physically produce the chosen word (see Friedman et al., 2013). So, lexical retrieval relies on different stages, each playing important, sequential roles.

Given such complexity, semantic errors in speech are bound to occur in everyday life (Sartori et al. 2005; Navarrete et al. 2010; Oppenheim et al. 2010; Navarrete et al. 2012; Belke and Stielow 2013). Semantically driven errors are errors in which words closely related in meaning are confused at the point of selection, leading to unintended consequences. We may, for example, produce a *slip of the tongue* when referring to our pet dog as a *cat*. Another example would be a *tip of the tongue* state, whereby the speaker is temporarily unable to settle of the intended word despite the meaning of the word being consciously accessible (James 1890). On the other hand, several studies have shown that under controlled conditions, the selection of the correct word is slower and more prone to error when conducted in the midst of competing semantically related words, an effect known as semantic interference (Caramazza and Costa 2000; Howard et al. 2006; Belke and Meyer 2007; Piai et al. 2011; Navarrete et al. 2012).

Recently, new insights come from computational models (Roelofs 1997; Howard et al. 2006; Oppenheim et al. 2010), brain stimulation studies (Devlin and Watkins 2007; Cattaneo et al. 2011; Henseler et al. 2014; Krieger-Redwood and Jefferies 2014), neuroimaging (de Zubicaray et al. 2001; Indefrey and Levelt 2004; Abel et al. 2009; Zubicaray et al. 2014) and studies with neuropsychological patients (Schnur et al. 2006; Jefferies et al. 2007; Corbett et al. 2009; Noonan et al. 2010). These studies argue that such semantic interference as well as selection errors may arise from either bottom-up, activation and/or inhibitory processes or top-down control processes, which guide selection of the target word in accordance with the current goals of the speaker (Jefferies et al. 2007; Hoffman et al. 2010; Whitney et al. 2011b).

In this chapter, I will describe models of semantic processing which conceptualize different mechanisms underlying lexical retrieval. Then I will describe the extent in which semantic interference and semantic errors are bound to occur in healthy individual as an effect of experimental conditions (Brown 1991; Burke 1991), the role of different mechanisms in modulating semantic interference and what happens when language brain areas that support those mechanisms are compromised after a brain injury. Specifically, the first paragraph highlights different mechanisms supporting lexical retrieval. The second paragraph will report semantic errors and semantic interference in healthy population in different experimental paradigms, such as semantic cumulative interference (Howard et al. 2006; Navarrete et al. 2010; Oppenheim et al. 2010), cyclic blocking (Belke 2008; Navarrete et al. 2012) and short-term memory task (Martin and Chao 2001; Hamilton and Martin 2007; Atkins and Reuter-Lorenz 2008; Atkins et al. 2011). Then, third paragraph will report the contribution of different mechanisms in modulating semantic interference and semantic errors in a healthy population. The fourth chapter will focus on those studies aiming to investigate the nature of both semantic interference and sematic errors in aphasic patients. In the last paragraph, I take into account the over and under activation account and its implementation in an inhibition model. This working model has been conceived here as a backdrop within which to frame all the studies reported in my thesis.

Mechanisms underlying lexical retrieval

Lexical retrieval has been conceptualized as a hierarchical multi-staged network in which single units or nodes are usually arranged in three main layers representing conceptual, syntactic, and phonological information (see figures 1 and 2).

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Figure 1. *Example of a hierarchical multi-staged network of lexical retrieval (Dell et al. 2014).*

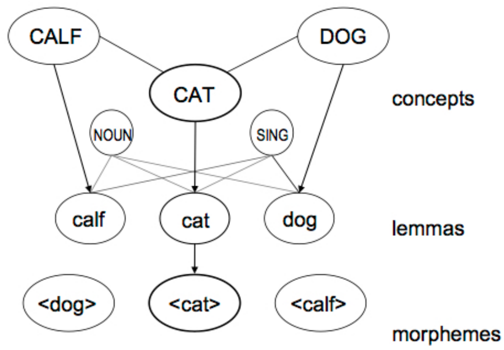

Figure 2. *Example of a model of lexical access in speaking production (WEAVER++, Roelofs 1997; Levelt et al. 1999). Excitatory connections are highlighted in bold.*

Each layer has its own representation: semantic concepts (non-decompositional theory; see Roelofs 1997; Levelt et al. 1999) or semantic features (decompositional theory; see Dell et al. 1997; Foygel 2000), lemmas (a lexical representation of a word which contains syntactic properties of that word) and phonemes, respectively. Furthermore, each node is interconnected with the nodes within the layer and with those in the layer below by excitatory links. This structure reflects the activation based traditional network models of lexical retrieval (hereafter *activation models;* Roelofs 1992; Dell et al. 1997; Roelofs 1997; Dell et al. 1999; Levelt et al. 1999), in which each unit has a level of energy or activation and the retrieval or activation of one node causes cascading activation down the layers via spreading of activation (Collins and Loftus 1975; Dell et al. 1997; Roelofs 1997; Levelt et al. 1999; Foygel 2000; Chen and Mirman 2012).

Consistent with activation models, in a picture naming task, the presentation of a picture (e.g. cat) activates the associated concept (Roelofs 1993; Roelofs 1997; Levelt et al. 1999) and/or its features (Dell et al. 1997; Foygel 2000; Chen and Mirman 2012) at the semantic level. This activation spreads among lexical units whose semantic features are partly overlapping with the target (parallel activation; see McClelland and Rumelhart 1981; Wheeldon and Monsell 1994). Lexical retrieval occurs when the target unit reaches a given activation threshold (absolute threshold; Dell et al. 1999; Morton 1970) or when its activation overcomes that of the other nodes (relative or differential threshold; Meyer and Schvaneveldt 1971; Luce 1959, 1990; Roelofs 1999; Levelt et al. 1999): the corresponding word is then selected and finally produced (e.g. winner-take-all process; Riesenhuber and Poggio 1999; Oster et al. 2009; Oppenheim et al. 2010).

Other models of lexical retrieval (hereafter *inhibition models*; Stemberger 1985; Harley and MacAndrew 1992; Harley 1993; Chen and Mirman 2012) include the traditional activation model, plus forms of cross-inhibition between similar lexical entries (Figure 3).

Figure 3. *Example of an inhibition model (Chen and Mirman 2012).*

Inhibition would rely on semantic similarity, thus the more two concepts are similar (e.g. they share features), the more the two corresponding lexical entries should inhibit each other in order for the correct word to be produced. Furthermore, inhibitory connections play an important role in speeding up lexical retrieval since they dampen the activation coming from competitors. Chen and Mirman (2012; see also Harley and MacAndrew 1992; Harley 1993a; Harley 1993b; Dell & O'Seaghdha 1994 for similar models) implemented a three-layer structure representing semantic features of concepts, lexical elements (lemmas), and the word form (phonemes and letters), consistently with the activation models. However, at the lemma level, they posited bidirectional inhibitory connections in which the unit that became active dampened down its competitors at the same level

(Figure 3). Specifically, the authors posited that inhibitory connection strengths were scaled by a sigmoid function of unit activation so that "weakly active word units had very little inhibitory effect on other word units, and strongly active word units had a very strong inhibitory effect on other word units" (p.4).

Consistent with inhibitory models, in a picture naming task, the activation of semantic features would flow down, to lemma level, in which the activation of a given unit inhibits the others who share the same semantic features. Differently from the previous activation models in which retrieval occurs when a given unit reaches either an absolute or relative threshold, in the inhibitory models, lexical retrieval occur only when the target crosses an absolute activation threshold (see Wheeldon and Monsell 1994). Finally, upon the naming of a picture, "priming" mechanisms occur, i.e., the retrieval of a word will facilitate its successive selection (repetition priming; Wheeldon and Monsell 1994; Hernandez and Reyes 2002; Howard et al. 2006; Oppenheim et al. 2010), by making the target word more accessible or its semantic neighbours less accessible. Early models (Brown 1981; Biegler et al. 2008) ascribed priming to either a temporary residual activation of the target or a temporary inhibition of its semantic neighbours. Consistently with these models, priming should be expected to decay rather quickly as a function of time. For example, as argued by Bock and Griffin (2000), the activation levels that control language production should decay quickly in order for production to succeed (see also Dell 1986). Similarly, the effects of inhibitory processes in production would be also time-bound. In contrast to this view, some authors posited that repetition priming relies on quite permanent processes (e.g. incremental learning), which are not affected by time or by unrelated items. In their model, Howard et al. (2006) proposed that repetition priming reflects durable effects in the mapping from semantics to lexical phonology. Specifically, they ascribed the priming phenomenon to the permanent strengthening of connections between semantic and lexical nodes. A similar model has been also posited by Oppenheim et al. (2010), who, consistently with Howard and colleagues, assumed that the retrieval of a target word reinforces its semantic-to-lexical connections. However, their model differs in the extent to which those connections that are not used, but semantically related to the named picture, are weakened or inhibited. Since both Howard's and Oppenheim's models rely on permanent changes, hereafter we will refer to them as *incremental learning models*.

Importantly, here after we referred to activation, inhibition and priming mechanisms as "bottom-up" mechanisms since they do not require any form of control from external executive processes.

Semantic errors and semantic interference in healthy subjects

In healthy subjects the most common type of slips of the tongue are word substitution errors (Burke 1991). However, people also experience the so-called *tip of the tongue* phenomenon, in which the speaker is simultaneously rendered capable of retrieving knowledge of a desired word but not the word form itself. A momentary lapse in either activation or retrieval processes are thought to underlie such phenomena. Although speech errors can be explained as an impairment as one or the other process, activation and retrieval play, by no means, mutually exclusive roles in the production of speech errors. Various paradigms have been developed in order to investigate mechanisms governing lexical selection by manipulating the semantic context in which words are selected for speech (Rosinski 1977; Lupker 1979; Schriefers et al. 1990; Belke et al. 2005; Howard et al. 2006; Schnur et al. 2009; Navarrete et al. 2012). A good example is the continuous picture naming task (Howard et al. 2006). In one such task, participants are provided a sequence of pictures to name, and embedded within this sequence are five exemplars from 24 semantic categories. Typically results report a linear increase in reaction times irrespective from the lag across all the categories (Alario et al. 2000; Howard et al. 2006; Navarrete et al. 2010). Interestingly, such linear increase was not found in a word naming task (Navarrete et al. 2010) showing that this effect origins at post-semantic level. de Zubicaray et al. (2013) in a fMRI study with a cumulative semantic interference paradigm, found an increase of the perfusion signal as a monotonic function of ordinal position in the left middle temporal gyrus (lMTG). By contrast, the pattern of activation in left inferior frontal gyrus (lIFG) was different with the signal that decreased for the first three positions followed by an increase later for the last two positions. The results replicate previous results in which MTG playing an important role in lexical selection and IFG in the top-down interference resolution.

Although the previous paradigms studying semantic interference, it is impossible not to conflate retrieval and selection processes. The cyclic blocking naming task (Kroll and Erika 1994; Damian et al. 2001; Belke et al. 2005; Hsiao et al. 2009; Navarrete et al. 2012) however, can help to separate these two processes. In this paradigm, participants repeatedly name sets of either semantically related or unrelated pictures. In the first repetition (or cycle), retrieval mechanisms are recruited to retrieve candidate words for subsequent selection. In other words, in the first cycle the demand on retrieval processes is high. Moreover, retrieval demands are higher in the unrelated condition since the retrieval of a semantically related word will also cause the co-activation of semantic neighbours. This explanation is largely consistent with the usual finding that during the first cycle participants are slower to name stimuli than in subsequent cycle. In cycles following cycle one, however, the demand on retrieval is reduced. In these cycles participants are naming the same stimuli repeatedly and, therefore, do not need to retrieve the target word every time a given picture is presented. Instead, the retrieved items remain active, and, as a result, make selection difficult. Thus, resources are shifted away from retrieval to selection processes. This is reflected in the not only the reduction of naming latencies following cycle one (i.e., a reduction in retrieval demands) but also in the magnitude of this reduction. The typical finding is that name latencies are higher in the semantically related condition compared to the unrelated condition, which is consistent with previous work showing that an active cohort of semantically related words slows down target selection (Schnur et al. 2006). In an fMRI study (de Zubicaray et al. 2014), authors showed a decrease of the perfusion signal in MTG from the second cycle onward associated with the interference effect in the homogeneous condition, arguing that the semantic interference for the list originate at lexical selection level. Again, they corroborate the hypothesis that MTG subtend a bottom-up concepts processing, modulated by the activation of both a target representation and semantically related competitors.

Finally, interesting results have been shown using short-term memory task. These studies highlighted the strong influence of semantic context in short-term retrieval (Martin and Chao 2001; Hamilton and Martin 2007; Atkins and Reuter-Lorenz 2008; Atkins et al. 2011). For example, Atkins et al. (2011) investigated the performances of healthy volunteers in a paradigm (the semantic probe task) in which semantic categories were incorporated into a standard recent-probes task (Berman et al. 2009). In this task, participants were provided a list of four semantically related or unrelated words. Then, after a retention interval, a single probe word was shown. The probe word could or could not be related with preceding sequence of words and participants needed to decide whether the probe was one of the words in the set. Results showed that short-term memory was susceptible to semantic interference: participants falsely identified a probe word as being a member of a previously presented list when the probe was semantically related with list items. Atkins and colleagues argued that their results were consistent with the contextual-cueing model (Nairne 2002), in which successful memory retrieval relies on an accurate recombination of activated cues associated with various features of the memoranda (e.g. semantic). So, a reduction in the distinctiveness of semantic features, or contextual cues that distinguish probes from the memoranda, would induce interference.

In conclusion, all these tasks show the extent in which presenting semantically related stimuli close in time and space can interfere with target selection. Indeed, activation of a target word may proliferate, or spread, amongst a cohort of semantically alternative response options, thereby increasing demands on selection, and making the selection of target slower and more prone to errors.

The role of bottom-up and top-down mechanisms in the emergence of semantic interference

The role of activation, inhibition and priming in modulating semantic interference

Bottom-up mechanisms have been conceived to play different roles in the emergence of semantic interference, namely the slowing of lexical retrieval when it is conducted in the midst of semantically related objects. However, the contribution given by activation, inhibition and priming mechanisms in generating semantic interference may vary, especially in regard to the model taken into account (see Spalek et al. 2013 for a review).

1. Activation models. Consistently with the activation-based traditional network models, the semantic interference effect may be conceptualized as emerging from the co-activation of similar semantic/lexical nodes, which can compete with each other, delaying the production of the target (Vitkovitch and Humphreys 1991; Roelofs 1992; Foygel 2000; Damian et al. 2001; Belke et al. 2005). In other words, this approach assumes that when we name a member of a given semantic category (e.g. dog), the activation of a given representation spreads to other exemplars of the same category (e.g. fox, wolf, cat). This exceeding activation cascades down from the semantic to the lexical level, thus creating high competition. This competition will delay the point at which the target reaches the activation threshold. Furthermore, when a target is retrieved, the just-produced word and its associated feature nodes may maintain high activation levels which persist for only a short period of time (residual activation: Collins and Loftus 1975; Anderson, 1996; Bock and Griffin 2000), acting as a strong competitor for the retrieval of a subsequent related item.

2. Inhibition models. These models posit that the semantic interference effect may be thought as a by-product of inhibitory mechanisms (Gurd and Oliveira 1996). Indeed, interference may result from temporary inhibition of the representation of a just-produced item and its closely related semantic competitors (Brown 1981; Harley 1993b; Vitkovitch 1996; Vitkovitch et al. 2001; Brown et al. 2005; Wheeldon 1989). For example, if there is lateral inhibition between candidates at the lemma level, when we name members of a given semantic category, the target higher activation level in the lexicalization process will tend to suppress the activation of the competitor candidate, inducing a so called refractory state (Warrington and Shallice 1979; Warrington and McCarthy 1983, Warrington and Cipollotti 1996; Forde and Humphreys 1997; McCarthy and Kartsounis 2000; Belke and Meyer 2007; Forde and Humphreys 2013; Mirman and Britt 2014). Doing so, inhibition will delay its future retrieval.

3. Incremental learning models. These models assume semantic interference as relying on the adjustment of semantic to lexical connections (priming) which contributes to increase semantic interference in two different ways. On the one hand (see Howard et al. 2006), the correct selection of a target primes its successive retrieval, which makes it a stronger competitor when another, semantically related, word has to be retrieved. On the other hand (see Oppenheim et al. 2010), lexical retrieval of a word reinforces its semantic-to-lexical connections, but also weakens non-target lexical nodes, making their successive retrieval slower. Incremental learning models highlight the important contribution of priming mechanisms in generating interference.

Empirical evidence supporting the role of activation in generating semantic interference comes from different experimental paradigms, namely the picture-word interference (PWI: Glaser & Dungelhoff 1984; Rosinski 1977; Schriefers et al. 1990; Costa et al. 2005; Piai et al. 2012) and the cyclic blocking naming (Damian et al. 2001; Belke et al. 2005; Abdel Rahman and Melinger 2009; Navarrete et al. 2012; Belke 2017). In the PWI task participants are instructed to name a target picture and ignore a distractor word that is presented usually in written form. In the critical condition, the target and the distractor are semantically related. In such a task, the usual finding is that in the critical condition participants are slower and less accurate compared to a condition in which an unrelated distractor is present. Consistently with the activation models, Schriefers and colleagues (1990) posited that interference is caused by co-activation of the distractor and the target words. That is, the related targets and distractors may exchange activation via shared conceptual codes, which would benefit the distractor more than the target and hence delay target retrieval (see Roelofs 1992).

In the cyclic blocking naming paradigm, participants repeatedly name sets of either semantically related or unrelated pictures. In the first repetition (or cycle), retrieval mechanisms are recruited to retrieve candidate words for subsequent selection. The typical finding is that during the first cycle participants are slower to name stimuli than in subsequent cycles due to repetition priming. More importantly, naming latencies are higher in the semantically related condition compared to the unrelated condition. Belke et al. (2005) argued that the semantic blocking effect relies on activation mechanisms. That is, when a picture is named, competitors from the same semantic category are activated.

Subsequently, on the next trial, if one of these competitors has to be named, the residual activation of the previous target word and the activation of the other competitors will slow the retrieval of that word.

In contrast with the activation models, another body of evidence attributes semantic interference to inhibitory mechanisms (e.g. lateral inhibition). For example, Brown (1979) in a series of experiments showed that producing a word after its definition is worsened when the definition was preceded by a semantically related word, but not when the word was orthographically related or unrelated. Furthermore, increasing the number of semantically related words before the definition resulted in worse performance in terms of speed. The author attributed these results to an "automatic spreading inhibition in the retrieval network to complement the automatic activation process" (p. 76). Wheeldon (1989) also reported a large inhibitory effect in which normal subjects take longer to name pictures if a semantic competitor word has been previously produced. In his study, the author concluded that in order to correctly retrieve a target word in the semantic lexicon, the activation of its semantic neighbours needs to be decreased, while the target level of activation needs to be increased. Furthermore, other studies have attributed semantic interference in other tasks, such as the cyclic blocking naming, as the result of lateral inhibition (see McCarthy and Kartsounis 2000; Biegler et al. 2008; Spalek et al. 2013). For example, in the cycling blocking naming task the naming of a given word may temporary inhibit the representation of its closely related semantic competitors (spreading inhibition; Vitkovitch 1996; Vitkovitch et al. 2001), slowing their successive retrieval.

Activation and inhibition models attribute semantic interference to temporary changes in activation level of both the target word and its competitors. On the other hand, incremental learning models attribute semantic interference to long-lasting mechanisms such as priming. For example, Howard et al. (2006) showed that when participants continuously named a sequence of semantically related pictures (continuous picture naming), their reaction times and errors linearly increased with the presentation of each new category member (cumulative semantic interference). Importantly, cumulative semantic interference was not affected by the number of intervening items (lag) between each member of the category (see also Alario and Martín 2010; Navarrete et al. 2010; Runnqvist et al. 2012). In their study, Howard and colleague attributed cumulative semantic interference to three key components: a) *shared activation* amongst semantically related conceptual/lexical representations (Collins and Loftus 1975; McNamara 1992); b) *priming* (or strengthening) connections between semantic and lexical representation, after a lexical representation had been selected, to optimize future target re-selection; and c) *competition*, which can delay selection via lateral inhibition (Stemberger, 1985; Harley 1993) or a decision criterion (e.g., activity relative to other representations: Luce choice ratio, Luce, 1959; Meyer and Schvaneveldt 1971; Levelt et al. 1999; Roelofs 1999). Chiefly, the authors supported the idea that priming played a crucial role in amplifying this competition. That is, when a target is correctly retrieved, its semantic/lexical connections are strengthened, making it a strong competitor and thus slowing the successive retrieval of a semantically related word. Consistently with this idea in their computational simulation the authors showed that eliminating priming mechanisms (i.e. by setting increment value to 0) abolished the interference effect. Although the aforementioned models posit the contribution of activation, inhibition and priming in the emergence of semantic interference, they are difficult to test in healthy individuals since they lead to the same predictions (see Schnur et al. 2006): higher latencies. Furthermore, they assume that the participant will always get the answer right, it's just a matter of time for the activation level to reach the level of selection (Dell et al. 2014). However, the inspection of error types can be more revealing. For example, Vitkovitch and colleagues, by testing participants in a picture naming task under speeded deadline conditions, provided evidence consistent with the activation models, i.e., participants made more semantic errors and perseverations (Vitkovitch and Humphreys 1991; Vitkovitch et al. 2001; Vitkovitch and Cooper 2012). However, in another work, Vitkovitch et al. (1996; see also Campbell and Clark 1989), by analysing the temporal characteristics of the perseverations, found that perseverations were reduced to the immediately following trials, suggesting a brief inhibitory effect.

External control mechanisms of lexical retrieval and their role in modulating semantic interference

Some authors argued that when the lexical/semantic system experiences interference or a weak activation of any potential target, executive control mechanisms can be engaged in order to dissipate the interference by adjusting the activation of the target or inhibiting the activation of competitors (Ridderinkhof et al. 2005; Jefferies et al. 2007; Bedny et al. 2008; Schnur et al. 2009; Whitney et al. 2011; Shao et al. 2013; Krieger-Redwood and Jefferies 2014; Mirman and Britt 2014). However, these executive control mechanisms are proposed to be somewhat more general and external to the lexicon, thus they would operate to inhibit the activation of linguistic and non-linguistic representations when the cognitive demand is high (see Thompson-Schill et al. 1999; Ilshire and McCarthy 2002b; Novick et al. 2005; MacKay 1987). More specifically, they are triggered in those tasks, such as Stroop, PWI and cyclic blocking naming (Nigg 2000; Shao et al. 2013; Shao et al. 2014; Shao et al. 2015), where strongly competing responses are induced by the distractors. Executive control mechanisms need time to build-up, so they more likely affect the semantic interference effect in higher naming latencies. Shao et al. (2013, 2015) investigated this hypothesis by means of delta plot analysis during both PWI and cyclic blocking naming tasks. A delta plot represents the size of the interference as a function of the relative response time (e.g. quintile see De Jong et al. 1994). In such a plot, the absence of executive control inhibition would result in an increase of interference through all quantiles; conversely, when inhibition occurs, interference should decrease for the slowest quantile. Importantly, since executive control inhibition would intervene in the slowest quantiles (the last two), by calculating their slope it is possible to obtain a measure of an individual's inhibition ability. The authors found that the slope of the last quantiles correlated with the magnitude of semantic interference, suggesting that inhibition occurred to reduce the interference from semantic competitors.

Semantic errors and semantic interference in aphasia

Semantic interference and errors during speech production may occur after a brain damage. Especially when the lesion involved those areas well known to support language (e.g. inferior frontal gyrus and middle temporal gyrus). In the literature, interesting findings arise from a neuropsychological condition well known as aphasia.

In an early study, Kiran and Thompson (2003) compared the performances of healthy young and elderly people with non-fluent and fluent aphasic patients in a semantic decision task. In one such task, participants were shown a semantic category (e.g. bird) followed by a target word, and instructed to decide as fast and accurately as they could if the word belonged to the category. A key manipulation of this study was to display exemplars that were either typical (e.g., pigeon) or atypical (penguin). The results showed a difference between fluent aphasic patients and the other groups in terms of errors and reaction times, with fluent aphasics producing more errors and showing slower reaction times. Typicality also affected performance, this is all groups were more accurate when responding to typical items than atypical. However, groups differed in terms of speed with fluent patients showing higher latencies than young, elderly and non-fluent aphasics. Authors suggested non-fluent patients would overuse a comparison process between the target and the category prototype, thus the closer is the target item to the category prototype the better is patients' performance in term of speed and accuracy. Conversely, for fluent aphasic patients might show an impoverishment of the category boundary, resulting in a low accuracy for the atypical items.

Other evidences, suggest an impaired access to semantic memory in non-fluent patients, especially when lesion involves the left inferior frontal gyrus with a plausible preservation of the anterior temporal lobe (Noonan et al. 2010). This condition has been referred as semantic aphasia (SA; see Jefferies and Lambon Ralph 2006; Jefferies et al. 2007; Jefferies et al. 2008; Corbett et al. 2009). At first blush, SA shares many features with another neuropsychological condition, namely semantic dementia (SD). Both SA and SD patients display impaired performances for verbal and non-verbal semantic tasks (Jefferies and Lambon Ralph 2006; Corbett et al. 2009). However, their performances are qualitatively different. Jefferies et al. (2006), showed that despite similar multimodal deficits in SA and SD patients, they differed in terms of semantic processing. For example, in a cued-picture naming task, in which a phonemic cue precedes the presentation of a to-be-named picture (e.g. "d", for dog), SA patients' picture naming improved whereas no significant improvement was seen in SD patients. This evidence would suggest a preserved semantic store but an impaired access ability.

Consistently with this hypothesis, further studies (Jefferies et al. 2008; Noonan et al. 2010) report that SA patients are more sensitive to the executive requirements of semantic tasks, for example, they have difficulty in retrieve the subordinate meanings of ambiguous words and struggle to reject highly associated distractor words in synonym judgment (Noonan et al. 2010), but they benefit of a cue, because it reduces the requirement for internally generated semantic control.

Interestingly, other studies (McCarthy and Kartsounis 2000; Wilshire and McCarthy 2002; Schnur et al. 2006; Schnur et al. 2009), investigated semantic interference in aphasia. Schunr and colleagues (2006) investigated semantic interference in terms of accuracy and errors types made by Broca's and Not Broca's aphasic patients by means of cyclic blocking naming task. Authors reported an overall increase of semantic errors in related than unrelated block. Moreover, semantic errors were higher in Broca's aphasic patients than in Non Broca's patients, suggesting that Broca group was less adept at resolving the strong competition engendered by the blocking manipulation. Authors concluded that the growth of semantic errors in related condition supports the idea that semantic interference in Broca's patients originated in an exceeding activation of semantically related neighbours of a given concept. Furthermore, authors supported the idea that Broca's patients showed a damage of an extra-lexical mechanism that comes on-line to bias selection when the demands are high.

Despite these evidences, studies that tested semantic interference in aphasic patients are far to show a coherent pattern of results. For example, some studies (see Lambon Ralph et al. 2000; Gotts et al. 2002; Schwartz and Hodgson 2002; Hodgson et al. 2003) failed to report semantic interference in aphasic patients. One of the main reason of these results is that many studies investigate patients' performances in the context of a group study, but variability in terms of reaction times (Moreno et al. 2002) and symptomatology

(Nespoulous 2000) has been commonly described in aphasic patients, especially following subcortical haemorrhagic lesions (Krishnan et al. 2012). Obler et al. (1995) questioned to what extent groups of aphasic patients are homogeneous or not and highlight the critical aspect of subject selection and group studies in aphasiology. On the other hand, Olson and Romani (2011) argued that even though the aggregation of aphasic patients can be misleading, not aggregate can results in information loss. The authors suggested that the aggregation has to be relying on theoretical question as well as the characteristic of data. Finally, as I will discuss in the third paragraph, previously mentioned studies advanced the idea that retrieval in aphasic patients seems rely on a damage at level of top-down control mechanisms, which manage lexical access (Jefferies and Lambon Ralph 2006; Corbett et al. 2009; Whitney et al. 2011b) or modulate competition coming from semantically related neighbours of a given concept (Belke et al. 2005; Schnur et al. 2006). However, these studies did not take into account an activation mechanism (bottom-up), in which the target unit that reach a critical threshold is more likely to be chosen and a lateral inhibition, which suppress a cohort of words whose semantic specification is partly overlapping with the target (competitors).

Over and under activation account

Previously, has been described a wide range of semantic errors that may occur in everyday (Howard et al. 2006; Piai et al. 2011; Piai et al. 2012; de Zubicaray et al. 2013) and especially when language areas of the brain are compromised following a brain injury (Wilshire and McCarthy 2002; Schnur et al. 2006; Noonan et al. 2010).

Despite the heterogeneity of semantic errors (e.g. coordinate, superordinate, omissions, perseveration) observed in healthy and aphasic populations, recent efforts have been made to ascribe these errors to either bottom-up mechanisms (activation, inhibition and priming) or top-down selection process. Bottom-up mechanisms are intrinsic to any representational system, and drives important processes, including semantic retrieval and lexical selection (Levelt et al. 1999; Foygel 2000). On the other hand, top-down, executive functions are thought to perform a variety of roles, chief among them is a filtration process that bias activation of information for selection consistent with current goals (Schnur et al. 2006; Lambon Ralph et al. 2009; Telling et al. 2010).

In a healthy brain, these processes work together. In the case of lexical selection, for example, under normal conditions bottom-up processes initially activate semantically related words and suppress a cohort of words whose semantic specification is partly overlapping with the target by lateral inhibition. Thus, a given target word is selected when it reaches a given threshold of activation or when its level of activation exceeds its competitors (Levelt et al. 1999; Foygel 2000). However, there are conditions in which the target word is poorly activated (under-activation) or its competitions are strongly activated (over-activation) increasing the difficult for target selection. Top-down processes are recruited in order to resolve either eventuality by biasing activation of the target item or inhibiting competitors (Thompson-Schill et al. 1997; Kan and Thompson-Schill 2004).

Given this relationship between activation/inhibition and selection, semantic errors could easily be conceived as being a product of over-or under- activation. Indeed, over-activation would create a situation in which many candidate words are competing for selection, increasing the likelihood that a competitor is selected by mistake, leading to a so-called *slip of tongue*. Meanwhile, under-activation of a given word could slow selection and temporally prevent the speaker from uttering the intended word, a so-called *tip of tongue state*. The role played by the under-and over-activation is what I call “the over-under-activation account”. In the following section I will attempt to explain semantic interference and errors in both healthy and aphasia through the over and under-activation account.

In healthy subjects, different paradigms have been used to investigate the semantic interference effect. These tasks show how the activation of non-target semantic neighbours produces a negative effect on target selection (e.g. semantic cumulative interference, semantic interference in cyclic blocking naming and in semantic short-term memory task). It is well known that the activation of a semantic category produces a spread of activation to exemplars of that category (Collins and Loftus 1975; Chen and Mirman 2012) creating competition between within-category members thus slowing target selection. Collins & Loftus (1975), studying the intrinsic characteristics of this process, argued that the spreading of activation doesn’t proceed constantly through the entire network and for all members of a category, but this process decreases in function of the inter-item distance (or relatedness; e.g. the activation produced by the concepts “cat” will be greater for “dog” than for “robin”). This has been investigated at length by Vigliocco et al. (2002; 2004), who described how the distance between items affects the size of the semantic interference effect, with smaller distances (i.e., greater semantic relatedness) the higher is the semantic interference. These studies corroborate with the present idea that the semantic errors and interference originate from an over-activation of competitors.

On the other hand, few studies have investigated the under activation of a target in healthy participants, but a good example would be the *tip of tongue* (ToT) state. In this case, we have the information in memory, but the activation is insufficient to trigger selection. In an experiment by Gollan et al. (2014), bilingual participants whose dominant language was Spanish were provided a set of three Spanish primes and then asked to produce semantically related Spanish words for each. Participants were then asked to name pictures in their second language, English. On critical trials, one of the primes was a Spanish translation of the English picture name. Translated-primes significantly increased ToTs. In this case, the priming activated the representation of the target word in the first language (Spanish), but the target word in the second language (English) was under-activated, producing ToTs.

Insights into the over-under- activation account have also been gained from studies using non-invasive brain stimulation transcranial Direct Current Stimulation (tDCS) (Cattaneo et al. 2011; Pisoni et al. 2012) and Trancranial Magnetic Stimulation (TMS) (Devlin et al. 2003; Pobric et al. 2010; Krieger-Redwood and Jefferies 2014). For instance, Pisoni et al. (2012) examined performance on a cyclic naming task in participants after anodal (excitatory) tDCS was delivered to the left superior temporal or left inferior frontal gyrus. The authors found that anodal stimulation over superior temporal gyrus increased semantic interference, conversely, no interference was observed after IFG stimulation. Taken together these results would support the over-under-activation account. As predicted, increasing activation of lexical representations by excitatory tDCS increased semantic interference. Likewise, increasing activity within the frontal regions presumably provided further support for top-down selection processes directed at resolving interference.

Implementing the over-under-activation account in an inhibition architecture of sematic-lexical system: a working model for the present thesis

The over-under-activation-account may be implemented in both activation and inhibition models. For example, in activation based traditional network models of lexical access the retrieval or activation of one node causes cascading activation down from semantic level to lexical level. In such a model, semantic interference effect may be conceptualized as emerging from an overactivation of similar semantic/lexical nodes, which can compete with each other, resulting in a delay of the production of the target or the erroneous selection of its semantic neighbours. On the other hand, according to these models, the underactivation of a lexical representation should not produce semantic interference, due a lack of co-activation of similar semantic/lexical representations. Conversely, inhibition models posit that the semantic interference effect may be thought as an effect of the underactivation rather than of the overactivation. In other words, when we name members of a given semantic category, the target higher activation level in the lexicalization process will tend to suppress the activation of the competitor candidate, via lateral inhibition delaying its future retrieval.

In the present thesis I implemented the over-under-activation account in an inhibition architecture of the semantic-lexical system. In doing so, I proposed this model as a working model providing an interesting backdrop within which to frame all the experiments reported in the following chapters. Specifically, my model might be conceived as a traditional three-layer network, in which the layers represent conceptual, syntactic, and phonological information. Additionally, at lexical level, bidirectional inhibitory connections are thought, thus when a target unit becames active it dampens down its competitors at the same level (e.g. those nodes whose semantic features are partially overlapped with the target). The strength of these inhibitory connections is related to the activation of the word units, so the higher is the activation of word units, the stronger is the inhibitory effect. According to this model, when we name a picure, a jolt of activation flows down from semantic level to lemma level, in which the activation of a given unit inhibits the others who share the same semantic features. Furthermore, the higher is the activation of competitors coming from semantic level, the stronger will be the inhibition of their lexical representation at lemma level. Lexical retrieval occurs only when the target crosses an absolute activation threshold. In such a model, semantic interference origins at lemma level where the inhibition of a semantic neighbours will hamper its successive retrieval. Furthermore, the inhibitory effect, thus the semantic interference, should be directly connected with semantic similarity between the target and its competitors.
Relying on such a model, I argue that individuals' sensitivity to semantic context (e.g. the extent to which an individual is more focused on the semantic features shared by the members of the same semantic category, rather than their item-specific information) should modulate the activation of both target and its semantic neighbours at semantic level and, thus modulating the strength of the inhibition at lemma level and consequently the semantic interference. This hypothesis will be tested in the second chapter.
Consistently with the above mentioned inhibition models (Chen and Mirman 2012; Harley and MacAndrew 1992; Harley 1993a; Harley 1993b; Dell & O'Seaghdha 1994), in our working model, lateral inhibition is conceived to be time-bound rather than a long-lasting phenomenon. According to this hypothesis, semantic interference should dissipate over time if no other semantically related item is presented. This other hypothesis will be tested in the third chapter.
Finally, my working model might also explain word retrieval deficits in clinical populations, such as aphasics. For example, I assumed that in some aphasic patients, lexical selection among related items might compel the engagement of lateral inhibition, which in turn may inhibit competitors, making their successive retrieval more difficult. This condition might underpin anomia and higher semantic interference in aphasic patients. On the other hand,

other aphasic patients may have a damage at level of top-down inhibition mechanisms, which might result in an exceeding activation of semantically related competitors. In one such case, lexical retrieval should be reliant on spreading of activation across semantically related items. Consistently with this hypothesis, as soon as patients see a given picture, the activation spread through other members of that category and their corresponding names, resulting in the retrieval of any word that reach the threshold leading to semantic errors. Furthermore, when the word has been retrieved it might maintain a residual activation making that more prone to be retrieved again (within set errors or perseveration). These hypotheses will be tested at length in the fourth chapter.

Chapter 2: Cognitive styles modulate semantic context's effect in response selection: Evidence from field dependent and field independent participants

The so-called semantic interference effect is a delay in selecting an appropriate target word in a context where semantic neighbours are strongly activated. Semantic interference effect has been described to vary from one individual to another. These differences in the susceptibility to semantic interference may be due to either differences in the ability to engage in lexical-specific selection mechanisms or to differences in the ability to engage more general, top-down inhibition mechanisms which suppress unwanted responses based on task-demands. However, semantic interference may also be modulated by an individual's disposition to separate relevant perceptual signals from noise, such as a field independent (FI) or a field dependent (FD) cognitive style. We investigated the relationship between semantic interference in picture naming and in a STM probe task and both the ability to inhibit responses top-down (measured through a Stroop task) and a FI/FD cognitive style measured through the Embedded Figures Test (EFT). We found a significant relationship between semantic interference in picture naming and cognitive style -with semantic interference increasing as a function of the degree of field dependence- but no associations with the semantic probe and the Stroop task. Our results suggest that semantic interference can be modulated by cognitive style, but not by differences in the ability to engage top-down control mechanisms, at least as measured by the Stroop task.

Introduction

Presenting semantically related stimuli close in time and space (semantic context) can interfere with target selection (Belke et al. 2005; Howard et al. 2006; Navarrete et al. 2010). This is because the presentation of a semantic related stimulus may prime the activation of a cohort of alternative responses (competitors), making selection of the right target more difficult, a so-called semantic interference effect (Oppenheim et al. 2010; Belke and Stielow 2013). Semantic interference has been observed in different experimental paradigms manipulating the context in which stimuli are presented (Damian & Bowers 2003; Piai et al. 2012). A good example is the continuous picture naming task (Howard et al. 2006), in which participants name a sequence of pictures and embedded within this sequence there are sets of semantically related items. Typically, participants naming speed increases with presentation of each new category member in the sequence, in the order of roughly 30ms (Navarrete et al. 2010). Other studies have highlighted the strong influence of semantic context in short-term memory (Hamilton and Martin 2007; Atkins et al. 2011). For example, Atkins et al. (2011) investigated the performances of healthy volunteers with a paradigm (semantic probe task) in which semantic relatedness was manipulated in a recent-probes task (Berman et al. 2009). Participants were given a list of four semantically related or unrelated words. Then, immediately afterwards, a single probe word was shown which could also be either related to the words in the list or unrelated. Participants had to decide whether the probe was one of the words in the preceding list. Results showed strong effects of interference: participants made more false alarms and showed higher correct rejection latencies with lists where items were semantically related.

In conditions of high lexical/semantic interference (i.e. an exceedingly high activation of both the target and its semantic neighbours), control mechanisms must be engaged to inhibit the activation of competitors. These mechanisms may be either internal to the lexicon or more general operating across domains to inhibit the activation of interfering responses be they linguistic and non-linguistic (e.g., Thompson-Schill et al. 1999; Novick et al. 2009). These latter mechanisms may be tapped chiefly by a task like the Stroop, but they may also be operating in naming tasks (i.e., Picture-Word-Interreference, cyclic blocking naming) and STM tasks in condition of high interference (e.g., Nigg 2000; Hamilton and Martin 2007; Whitney et al. 2011; Shao et al. 2013; Krieger-Redwood and Jefferies 2014; Shao et al. 2015).

There is already some evidence that the mechanisms which control interference in lexical selection tasks are different from mechanisms which apply top-down to suppress task irrelevant responses based on task demands, as an experimental task like the Stroop. In a continuous naming task, selecting the right name for a picture is an ecological task and suppressing irrelevant names is an automatic process which is not under strategic control. This is very different from the Stroop which is an experimental task where responses need to be under strict control of the participant. In the Stroop, the names of written words (irrelevant to the task) is automatically activated and top-down control is needed to bias the activation of task relevant information (i.e. the ink color, see Khng and Lee 2014). Consistently with this description, the Stroop engages prefrontal cortex areas (Banich et al. 2000; Milham et al. 2001; Milham et al. 2002; Milham et al. 2003) while naming tasks - even those with high semantic competition- engage temporal brain areas such as the superior or the middle temporal gyrus (de Zubicaray et al. 2001; de Zubicaray et al. 2013; de Zubicaray et al. 2014). Another piece of evidence comes from a study of Dell'Acqua et al. (2007) which investigated the locus of interference in both Stroop task and Picture-Word Interference task (PWI). In the PWI task participants are instructed to ignore the distractor word whilst concurrently naming a picture. In critical conditions, the distractor and picture name are semantically related, and this makes responses slower and less accurate compared to an unrelated condition. In their study, Dell'Acqua et al. showed that, in a variant of the psychological refractory period (PRP) paradigm, PWI was underadditive with SOA effects i.e. the magnitude of semantic interference decreased as SOA was decreased. By comparing these data with those of Fagot and Pashler (1992) in which the Stroop effect was shown to be additive with SOA effects in PRP paradigm, they suggested that the interference effect in the PWI task arise at an earlier selection stage than the interference effect in the Stroop task.

In spite of some suggestive results, evidence regarding the nature of control mechanisms across tasks remain limited. Moreover, we know little of what determine individual differences in susceptibility to interference (e.g. Ridderinkhof et al. 2005). They may be due to differences in the ability to engage in lexical-specific selection mechanisms or more general, top-down mechanisms as discussed above. Still alternatively, differences in the size of the interference effect may be due to a general cognitive style which affects the ability to discriminate stimulus-specific information from a general background. The semantic context created by the previous presentation of a series of semantically related items may make more difficult to focus on the individualizing feature of an item. Thus, individuals who are more focused on shared features could be more prone to semantic interference, due to a higher co-activation of both the target and its related representations. Conversely, individuals who focus on item-specific information may show reduced interference. These different hypotheses make different predictions which we want to assess in our study.

If semantic interference is due to lexical-specific selection mechanics, we should find that semantic interference in picture naming is unrelated to interference effects in other tasks such as the Stroop or the Probe task where interference may be controlled by different mechanisms (top-down inhibition mechanism for the Stroop, phonological STM abilities for the probe). If selection mechanisms are related to top-down inhibitory abilities, instead, we should see a relationship across tasks and, in particular, with the Stroop. Finally, if semantic interference is related to a general ability to discriminate stimuli from a masking context (focusing on a discrete dimension and ignoring context), we should see correlations between tasks, but also that a correlation with a measure of interference in a perceptual task.

In our study, we are particularly interested in the hypothesis that semantic interference may be related to a cognitive style linked to the ability to separate signal from noise such as the field independent/field dependent (FI/FD) cognitive style (see Witkin et al. 1977). This style identifies two modalities of interaction with the environment. Highly FI individuals focus on discreet parts/dimensions of a perception independently of context. Highly FD individuals find more difficult to isolate discrete dimensions without being influenced by the context in which they are embedded and, thus, find more difficult to overcome or restructure a contextual organization when needed. Importantly, FI/FD refers to a tendency toward one mode of perception or another, rather than to a dichotomy: as stated by Witkin and colleagues (1977), “there is no implication that there exist two different types of human beings” (pp.13).

The early works on FI and FD made use of experimental paradigms such as the rod-and-frame test, the body-adjustment test, and the embedded figures test (EFT; see Witkin et al. 1977). These paradigms allowed computing a quantitative index of the extent to which the surrounding organized field influences a person's perception of an item. The rode-and-frame task assesses identification of the upright dimension in space. Participants are placed in a dark room, in which they can see only a luminous square framework with a luminous rod pivoted at its centre. Both the framework and the rod are shown in a tilted position, but the rod can be rotated clockwise or counter clockwise independently of the framework. The participants’ task is to adjust the rod to a perceived upright position, while the framework remains in its original position. People perform the task differently, with some being strongly influenced by the surrounding frame (FD) and others adjusting the rod close to its upright position regardless of the position of the surrounding frame (FI). Witkin stated that: “They [FI individuals] evidently apprehend the rod as an entity discrete from the prevailing visual frame of reference…” (pp. 5). In the body-adjustment task, participants are seated on a tilted chair located inside a small tilted room. Both, the chair and the room can be independently tilted clockwise or counter-clockwise by means of a rotating centrifuge arm. In this setting, the participants' task is to adjust the chair (and thus the body) to a perceived upright position. Finally, in the embedded figures test, participants must locate a simple geometric figure embedded in a complex one (see Figure 4 in the method section). The simple figure is concealed because its lines are used in various sub-parts of the complex design. This perceptually hides the simple figure. Results show that some people quickly recognise the simple figure in the complex design (FI), while others struggle (FD; Witkin et al. 1971). These different paradigms are reported to be consistent in identifying individuals as FI/FD (Witkin 1977; see also Witkin and Goodenough 1981).

The degree to which a semantic context (negatively) influences target selection may be related to field dependency. Highly FD individuals may be more sensitive to the influence of a general semantic field created by the features shared between a pictures and other pictures recently presented.

This would make selecting the right name for a target picture more difficult for two reasons: 1. It would be more difficult to focus on the perceptual identifying feature of the target and 2. It would increase the activation of semantically related items. In the first case, field dependency may modulate degree of interference in a picture naming task. In the second case, it would modulate it across picture naming and STM tasks (where words but not pictures are presented).

FI and FD cognitive styles have been reported to correlate with a broad range of cognitive processes, especially when they involve dis-embedding. Poirel et al. (2008) showed that an individual's disposition toward a global-local bias in a Navon task (where a larger shape is made of copies of a smaller different shape and the participant has to name either the larger or the smaller shape; see Navon 1977) was largely explained by FI/FD cognitive styles. The preference for the global shape linearly increased with the degree of field dependence. Other studies have reported correlations between field dependency and a variety of visuospatial tasks such as the road learning task (Mitolo et al. 2013), the visual pattern test (Borrella et al. 2007), the Minnesota Paper Form Board (MPFB, Likert and Quasha 1941), a spatial orientation task and a task involving the spatial transformation of a perceived object (Boccia et al. 2016). Finally, FI/FD cognitive styles have been shown to correlate with learning abilities (St Clair-Thompson et al. 2010; Nozari and Siamian 2015) and working memory capacity (Rittschof 2010), with FI individuals performing better (see Evans et al. 2013 for a review). However, to our knowledge, there is no evidence of whether cognitive styles can modulate semantic interference.

In our study, we explored the nature of interference effects by assessing inter-relations among tasks including a task assessing field-dependency. We assessed semantic interference in a continuous picture naming task and put the size of this effect in relation with interference effects in other tasks such as: a) a Stroop task which measures top-down control mechanisms related to inhibition abilities, b) a probe short-term memory task which measures interference not in lexical selection, but in recognition and, finally, c) an embedded-figure test which measures field-dependency with the ability to distinguish a figure from background. We predicted the following: 1. If semantic interference is controlled exclusively by lexical-specific selection mechanisms, there should be no relation between interference in picture naming and other tasks. 2. If semantic interference is controlled by top-down inhibition mechanisms, we should see a relationship between interference the Stroop task on one side and interference effects in picture naming and probe tasks on the other side, since all these tasks require task-dependent inhibition to an extent (see above). 3. Finally, if cognitive style related to field dependency modulates interference effects, performance in the embedded figures test may contribute to explain individual differences in semantic interference in picture naming and, possibly, in probe tasks, since in both of these tasks a stimulus needs to be distinguished from a semantic background. Instead, one may expect no relationship with the Stroop task which is based more on inhibiting an unwanted, automatic response rather than on discriminating the identifying features of a stimulus in a confusing background.

Method

Participants

52 participants were recruited from the University of Rome "Sapienza student community" (23 males; mean age = 26; SD = 3). Participants were all monolingual Italian native speakers. They were naïve to the purpose of the study. All claimed to have normal or corrected to normal vision and had no language impairment. All participants signed a consent form before the study began. This study was approved by the local ethics committee, in agreement with the Declaration of Helsinki (1964).

Materials and procedure

Cognitive style: The Embedded Figures Test (EFT)

Version A of EFT was used. It consists of a set of 12 cards depicting coloured, complex geometric figures and of a set of 8 cards with simple shapes (Figure 4; Witkin et al. 1971; Italian adaptation: Fogliani, Messina et al. 1984). Participants were first shown a complex figure for 15 seconds. This figure was then removed from sight and the simple shape was shown for 10 seconds. Finally, the complex figure was presented again, and participants were asked to locate the simple shape embedded in it and trace it with a pen. A practice trial was administered to familiarize participants with the task. Time was recorded with a stopwatch. Errors and very long responses were recorded with a maximum of 180 seconds (Fogliani, Messina et al. 1984). The score of each participant was computed by averaging the times needed to correctly identify the simple shapes. This score was taken as an index of individual field independence/field dependence. The higher the score, the higher the field dependence.

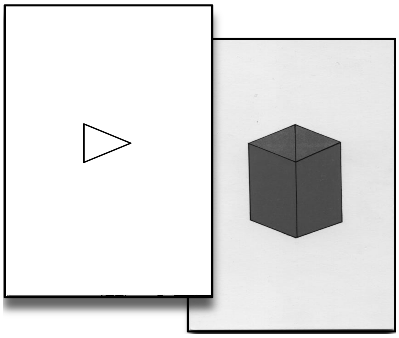

Figure 4. *An example of cards used for the Embedded Figure Test.*

Continuous Picture Naming

Stimuli. Participants had to name pictures. They were 82 line-drawing pictures (300x300 pixel dimensions) drawn from a variety of sources. 60 pictures were experimental and 22 were “fillers” (see Appendix 1). Experimental pictures were drawn from 12 semantic categories, with 5 exemplars for each category (Figure 5). Presentation of the stimuli followed Howard et al. (2006): the first and last five items were filler items; each category was presented in a sequence that separated category members by 2, 4, 6, or 8 intervening items (lag), which were either fillers or pictures from other categories; each category was assigned one of the 24 possible lag order sequences (4x3x2=24) and category members were assigned ordinal positions (i.e., 1 to 5) in the corresponding lag sequence. In the literature, this structure is well known to induce a linear increase of both reaction times (Howard et al. 2006) and errors (Navarrete et al. 2010) as a function of ordinal position (cumulative semantic interference). The size of the lag in this range does not affect the degree of interference. In other words, during this task, the previous naming of a picture (e.g. dog) will make the naming of a successive related picture (e.g. cat) slower and more prone to errors, but the number of intervening items (up to 8) does not matter. To make sure that positional effects were not confounded with lexical variables, items were matched across each ordinal position for frequency and word length (CoLFIS database; Goslin et al. 2014; see Appendix 2).

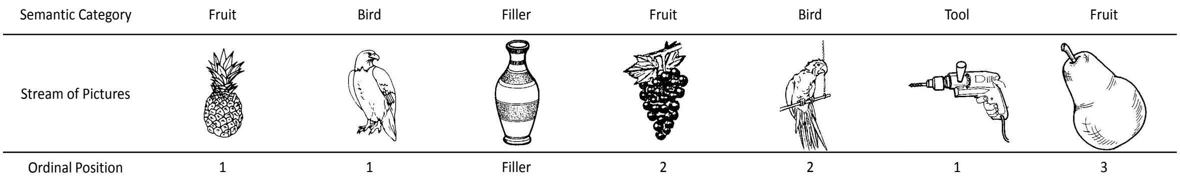

Figure 5. *Schematic representation of a sequence of trials in the Continuous Picture Naming Task*

Procedure. For this and the following tasks, participants were seated in a dark and noise-isolated room and stimuli were provided at the centre of a 21-inch LCD computer monitor with a resolution of 1024x768 pixels, 120Hz. The presentation of the stimuli and response times were controlled by means of SuperLab 4.0 software. Each naming trial started with the presentation of a fixation cross for 1000ms followed by a blank screen for 250ms. A picture was then presented and remained on the screen until the participant made a verbal response. RTs were taken using a Cedrus SV1 voice key.

The naming trial finished with a blank screen presented for 500ms and, then, the next trial started. Participants were instructed to name the pictures as fast and accurately as possible using bare, subordinate category nouns (e.g., a correct response to ant is “ant”, not “insect”). A brief practice session preceded the experimental task. Naming responses were scored off-line using a tape recorder. Responses were scored as incorrect if the name was incorrect or no response was given. Near-synonyms (e.g., “mule” instead of “donkey”) were scored as correct.

Stroop Task

Stimuli. Participants had to name the ink colour of words. Stimuli consisted of four colour words (BLUE, RED, YELLOW and GREEN) and strings of Xs (i.e. “XXXX”) printed in one of four colours (blue, red, yellow and green). There were three main conditions: neutral, congruent and incongruent (24 trials for each condition). In the neutral condition, a string of Xs was shown in one of the four possible colours. In the congruent condition, colour words were shown in their corresponding colours. Finally, in the incongruent condition, colour words were presented in a different colour (e.g. “RED” written with green ink). Participants were instructed to name the ink colour of the stimuli as fast and accurately as possible.

Procedure. Each trial started with a fixation cross presented at the centre of the screen for 1000ms, followed by either a word or a string of Xs. Stimuli remained on the screen until the participant gave a verbal response which triggered a Cedrus SV1 voice key. Words were displayed in uppercase, 56-point Times New Roman font. A brief practice session preceded the experimental task.

Semantic Probe Task

Stimuli. Participants were asked to recognize whether a probe word was present in a list of immediately preceding words. In each trial, five words were presented one at a time on a computer screen, followed by a probe word. All words were concrete nouns. Participants were asked to respond affirmatively if the probe was one of the previous five words (positive/yes trials) or negatively if not (negative/no trials). Lists were never repeated. There were 120 trials, overall, half positive and half negative. The negative trials included: a. No-Associated trials, where the words of the list were semantically related to each other and to the probe (e.g. cat, dog, mouse, rabbit, goat: probe: cow; N=20); b. No-Combined trials, where the words of the list were unrelated to each other but the combined meanings of two of them were related to the probe (e.g. vehicle, lobe, lizard, jewel, hostage: probe: earring; N=20); and c) No-Unrelated trials where the words of the list were neither related to each other nor to the probe (N=20). Positive trials were subdivided into a) Yes-related trials (words in the lists were semantically related to each other and to the probe; N=30) and b) Yes- unrelated trials (words were not drawn from the same semantic category; N=30). Figure 6 provides an illustration of the negative and positive trials.

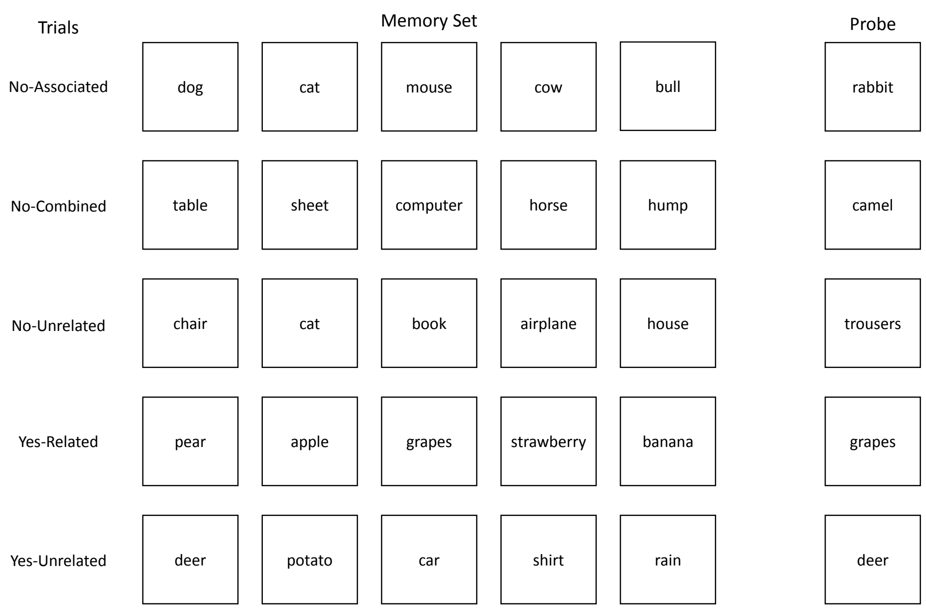

Figure 6. *Schematic illustration of the conditions in the Semantic Probe Task*

We wanted to contrast a no-associated condition with a no-combined condition with the expectation that field dependency may be related to the first but not to the latter. In the associated condition the categorical (and visual similarity) between the items may strongly activate a semantic field where common features are more salient than the distinguishing feature of the target. This may make the probe more difficult to distinguish from other items in the list especially for field-dependent individuals (thus producing a correlation between field-dependency and degree of interference). In contrast, in the combined condition, it is only the meaning of the (lure) probe which is strongly activated by the overlapping meanings of two words in the list. Therefore, degree interference in this condition may relate STM abilities and/or to lexical abilities in activating selective representations and inhibiting competitors, but not to field dependency.

We have not distinguished these two conditions in the case of positive trials. Here, a degree of association between related words may actually make a positive, correct response more likely. Results from the literature generally either do not report results for yes trials or report non-significant results compared to neutral conditions (Hamilton and Martin 2007; Atkins and Reuter-Lorenz 2008; Atkins et al. 2011).

Procedure. At the beginning of each trial, a fixation cross was presented in the centre of the screen for 1000ms, followed by five words presented one at a time. Each word stayed on the screen for 400ms and was separated from the following word by a blank screen for 250ms. The five words were followed by the probe word that remained on the screen until the participant gave a response. Participants gave “yes” and “no” responses by pressing the “g” and “j” keys, respectively. They were asked to respond as quickly and accurately as possible with the index finger of their dominant hand.

Data Analysis

Variable extraction

For each task, errors, responses below 250ms (false triggers) and above 3 standard deviations over the mean (outliers) were removed. Then, an interference index was computed on the remaining data as follow:

a) for the continuous picture naming, by averaging the RTs in the first two (hereafter “1+2”) and the last two (hereafter “4+5”) ordinal positions and then by calculating the difference between them ((4+5)-(1+2); Cumulative Picture Naming Interference or CPNI);

b) for the semantic probe, by computing the difference between 1. No-Associated and No-Unrelated trials (Interference No Associated), 2. No-Combined and No-Unrelated trials (Interference No Combined), and 3. Yes-Related and Yes Unrelated trials (Interference Yes). Additionally, in order to make a possible effect more reliable, we computed 4. an

Associated + Combined interference index by averaging the RTs in the No-Associated and No-Combined trials and subtracting them from those in the No-Unrelated trials (Interference No Associated + Combined);

c) for the Stroop task, by computing the difference between the incongruent and the congruent condition (Stroop Interference).

The mean and SD for each index and the EFT score were reported in Appendix 3.

All analyses were carried out on RTs. Errors were not analysed because they were too few.

Linear mixed models

To assess the relative contribution of different factors to explain interference effects in our tasks we fitted data from the naming, the Stroop and the probe tasks using linear mixed effect modelling (Baayen et al. 2008; Bates et al. 2015a; Bates et al. 2015b). In this kind of analysis, the dependent variable is modelled as linear combination of both fixed and random effects, with the latter contributing only to the covariance of the data. Linear mixed modelling relies on single trial data rather than the averages by subject (or other factors). In this way, the random and fixed effects are explicitly controlled for.

Linear mixed models were built by means of the “lme4” package (Bates et al. 2015a) implemented in R (R Development Core Team). Statistics for each model were computed by using the “lmertest” package for R (Schaalje et al. 1997). The function provides p-values calculated from F statistics. Furthermore, Kenward-Rogers approximation for degrees of freedom was computed. The KR method works reasonably well when sample sizes are moderate to small and the design is reasonably balanced (Schaalje et al. 1997). Finally, we run the “r.squaredGLMM” command (MuMln package) to calculate conditional and marginal coefficient of determination for generalized mixed-effect models. This command gives two main outputs, namely the marginal coefficient of determination (the variance explained only by fixed factors) and the conditional coefficient of determination (variance explained by both fixed and random factors) (Nakagawa and Schielzeth 2013).

For each task, three main models were created: a) a baseline model (m1), intended to test the main effect of interference. Here, experimental conditions were conceived as the main source of observed variance in RTs; b) a second model (m2), investigating the main effect of both task condition and cognitive style on participants’ performance. This model assumed an amount of unexplained variance in the first model accounted for by FI/FD styles; c) a third model (m3), investigating the interaction between task condition and cognitive style as another source of variance in RTs. It assessed whether FI/FD styles modulated the size of interference. These models were compared in their fit of the data. If cognitive style modulates performance in our tasks, the third model would explain the data better.

Finally, we created a global model where Stroop and probe interference scores as well as EFT scores, as a measure of field-dependency, were entered as predictors of performance in continuous picture naming. We wanted to determine which variable if any was associated to semantic interference during lexical access.

Correlational Analyses

We assessed correlations between our measures of interference and the EFT scores using Pearson bivariate correlations. A Bonferroni correction for multiple comparisons was applied.

Results

Linear mixed models

Continuous picture naming

Incorrect responses (2%) as well as false triggers and outliers (2%) were excluded from analysis. Remaining RTs were log transformed to reduce skewness and to approach a normal distribution and were submitted to linear mixed modelling (see Runnqvist et al. 2012). In the first model (CPN-m1) ordinal position was treated as a fixed factor and participants as a random effect. Results reported a significant effect of Ordinal position ($F_{1,207}$= 73.98, $p < .001$; Figure 7). In the second model (CPN-m2) EFT scores were added as a fixed factor. Results confirmed the significant main effect of Ordinal position ($F_{1,207}$= 73.98, $p < .001$), but also showed a significant main effect of EFT score ($F_{1,50}$= 10.23, p= .002). This indicates that individuals who are more field-independent have faster naming latencies. The third model (CPN-m3) investigated the interaction between Ordinal position and EFT as a fixed factor. This model showed a significant effect of Ordinal position ($F_{1,206}$= 5.09, p= .02), no significant effect of EFT score ($F_{1,108}$= .81, p= .36), but a significant Ordinal position by EFT interaction ($F_{1,206}$= 8.42, p= .004; Figure 8). That is, the higher the FD the higher the semantic interference effect.

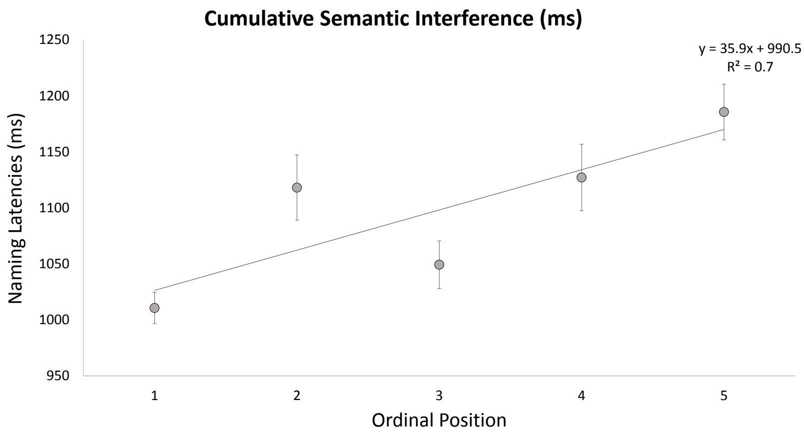

Figure 7. *Linear increase of naming latencies in function of ordinal positions. Error bars report the standard error. Continuous lines depict the linear trend. The equation of linear trend as well as the R2 have been reported.*

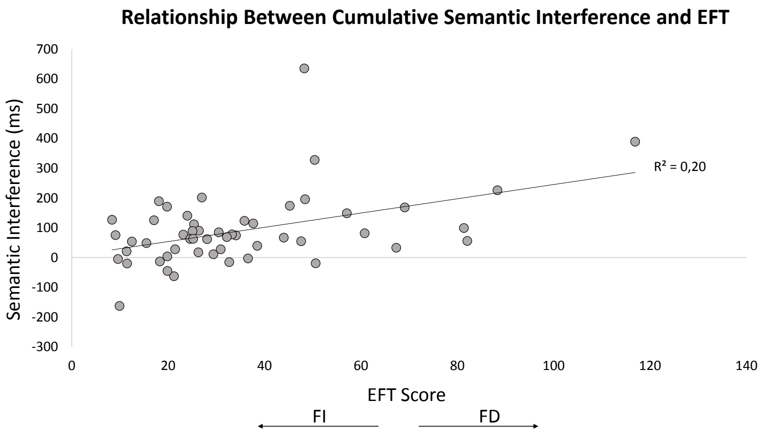

Figure 8. *Scatterplot. The EFT score is reported on x-axis, whereas on y-axis is represented the cumulative semantic interference index computed as the difference of the averaged reaction times in the last vs the first two ordinal positions ((4+5)-(1+2). R2 shows the size of their positive linear relationship.*

A formal comparison of these models showed that the third model's fit was better than CPN-m1 ($\chi^2_{(1)}$ = 9.68, p= .001) and CPN-m2 ($\chi^2_{(1)}$ = 8.33, p= .003; see Appendix 4 for additional information about each model). Subsequently, to test the reliability of our results, another version of the same three models were created (CPN-m1b, CPN-m2b and CPN-m3b), with the slope of the ordinal position allowed to be different for each participant. These models replicated our previous results and are reported in Appendix 5.

Stroop task

Errors (1%) and false triggers and outliers (2%) were excluded from analysis. The remaining data were log transformed and submitted to three mixed models as before. In the first model (ST-m1), Stroop conditions (congruent, incongruent and neutral) were treated as fixed factors and participants as random factors. This model highlighted a significant effect of Condition ($F_{2,100}$= 134.98, p < .001). Tukey corrected post-hoc comparisons showed that the incongruent condition differed from the Congruent (p < .001) and Neutral conditions (p < .001). Furthermore, latencies in the Neutral condition were faster than in the Congruent condition (p= .02). In the second model (ST-m2), the EFT score was added as an additional predictor. ST-m2 reported a significant effect of Condition ($F_{2,100}$=134.98, p < .001), but no significant effect of EFT ($F_{1,49}$=1.96, p= .16). Finally, the third model (ST-m3) tested the interaction between Stroop conditions and EFT score. Results confirmed an effect of Condition ($F_{2,98}$= 36.93, p < .001), but there was no effect of EFT ($F_{1,49}$=1.96, p= .16) and no interaction EFT x Condition ($F_{2,98}$= .07, p= .92; Figure 9). Model comparisons failed to highlight any statistically significant difference (Appendix 6).

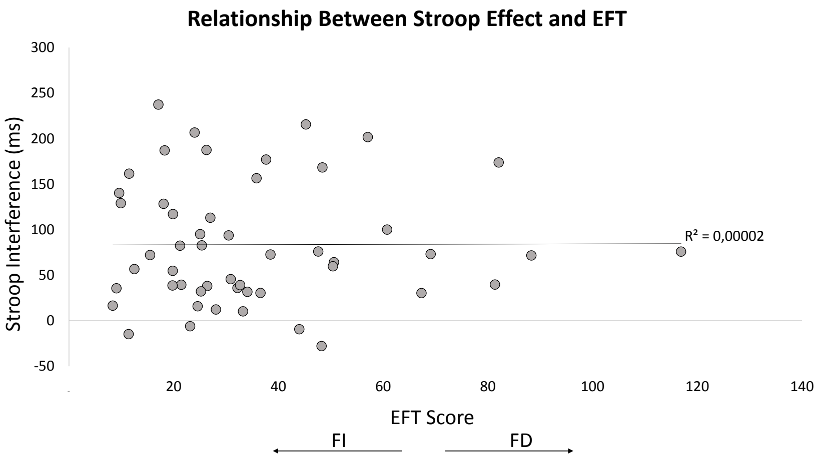

Figure 9. *Scatterplot. The EFT score is reported on x-axis, whereas on y-axis is represented the Stroop interference index computed as the difference between incongruent and congruent condition. R2 shows the size of their positive linear relationship.*

Semantic probe

Errors (7%) as well as false triggers and outliers (3%) were excluded from analysis. The remaining data were log transformed and submitted to a linear mixed model analysis. Interference effects for the following conditions were separately analysed: No-Associated, No-Combined, No-Associated + Combined, Yes-related. Three types of models were created as before. For No-Associated condition, the first model (SPna-m1) tested the significance of the interference effect induced by No-Associated condition; the second model (SPna-m2) added EFT, and the third model (SPna-m3) considered the interaction between interference and EFT scores. For all models, participants were treated as a random factor.

The first model (SPna-m1) showed significant effects of interference ($F_{1,46}$= 32.48, p < .001) with higher latencies in the Associated condition as compared to the Unrelated. The second model (SPna-m2) confirmed significant interference effects ($F_{1,46}$= 32.48, p < .001), but showed no effect of EFT ($F_{1,45}$= 2.71, p= .10). A formal comparison of SPna-m1 and SPna-m2 did not show a significant improvement in the model fit ($\chi^2_{(1)}$ = 2.75, p = .10). Finally, the third model confirmed significant effects of interference ($F_{1,45}$= 9.60, p= .003), but showed neither a main effect of EFT ($F_{1,45}$= 2.71, p= .10) nor any interactions between interference effect and EFT ($F_{1,45}$=.0005, p= .98; Figure 10A). A formal comparison between SPna-m2 and SPna-m3 showed no improvement in fit ($\chi^2_{(1)}$ = .002, p = .98) (Appendix 7). Similar results were obtained for the No-Combined condition (see Figure 10B and Appendix 8) and when an averaged interference effect was considered (No-Associated + Combined; Appendix 9). On the other hand, there were no significant interference at all (positive or negative) with the Yes-related condition (Appendix 10).

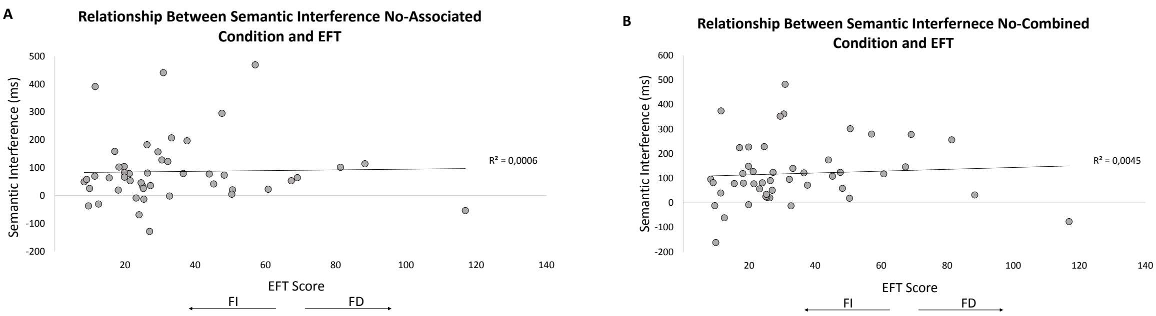

Figure 10. *Scatterplot. The EFT score is reported on x-axis, whereas on y-axis is represented: (A) the semantic interference in No-Associated trials computed as the difference between No-Associated and No-Unrelated conditions (Interference No Associated); (B) the semantic interference in No-Combined trials computed as the difference between No-Combined and No-Unrelated conditions (Interference No Combined). R2 shows the size of their positive linear relationship.*

Global model

Here, we considered interference in the Stroop and probe tasks and EFT scores as predictors of interference effects in picture naming. First, since our previous analysis reported similar results for the No-Associated and the No-Combined condition in the probe task, we collapsed them into a more general Associated + Combined interference score. To place EFT scores, the Stroop interference and the probe interference scores on an equal footing, we converted them in z-scores. These scores were submitted to a linear mixed modelling together with the ordinal positions as fixed factors. Participants were treated as random effect.

Results confirmed a main effect of the Ordinal position ($F_{1,172}$=53.32, p< .001) and a significant Ordinal position by EFT interaction ($F_{1,172}$=4.63, p= .03). No other effects were significant (Appendix 11).

Correlational Analysis

There was a significant correlation between the interference effect in continuous picture naming and the EFT (Pearson r= .46, p=.01). There was also a significant relation between Interference Associated and Interference Combined (Pearson r= .61, p < .001). There were no other significant correlations (A complete set of correlations is reported in Appendix 12).

Discussion

This study was aimed at investigating the nature of semantic interference effects by focusing on: a) the inter-relations of semantic interference in different tasks (continuous picture naming and semantic probe); b) the relation of semantic interference with a more general disposition to suppress interference coming from competitors (measured through a Stroop task); c) the extent to which the amount of semantic interference may be modulated by individual predisposition towards the perception of part of a context as discrete from the surrounding field or as a whole, namely field independent (FI) and field dependent (FD) cognitive styles; d) whether FI/FD cognitive styles modulated interference in all of the tasks.

Results in the correlational analysis showed that semantic interference in the continuous picture naming did not correlate with semantic interference in the semantic probe. Although we should be cautious to interpret null effects, results were consistent with an account which suggests that semantic interference in naming is due to lexical-specific selection mechanisms and did not arise at conceptual level (Damian et al. 2001; Riley et al. 2015). Indeed, if the semantic interference had occurred at conceptual level, we would have found a correlation between semantic interference in the continuous picture naming and semantic probe. In a series of studies, Belke and Stielow (2013; see also Riley et al. 2015) assessed the semantic interference in a continuous picture naming task and in a cyclic blocking naming task, in which the naming of a set of pictures is slower when participants repeatedly naming sets of semantically related versus unrelated pictures. In both tasks participants were instructed to either name a set of pictures or classify those pictures (man-made vs. natural; semantic classification). The authors found that semantic interference occurred during naming, but disappeared when the same pictures were categorized, supporting the evidence that this phenomenon was not likely a conceptual effect.

Correlational analysis also failed to report a significant relation between semantic interference in both continuous picture naming and semantic probe and the interference in Stroop task. Though we should still be cautious to interpret this result, it would support the idea that semantic interference cannot be conceived as a by-product of a top-down inhibitory mechanism (Costa et al. 2009; Riès et al. 2015; Rose and Abdel Rahman 2016). Such a result contrasts with other studies in the literature, which conceive top-down inhibitory mechanisms (e.g. executive control mechanisms) to play a role in generating interference in those tasks, such as Stroop, where strongly competing responses are induced by the distractors (e.g. Milham et al. 2003). For example, Schnur et al. (2006) stated that "In line with the executive selection hypothesis, we now suggest that ''too much excitation'' among lexical-level competitors constitutes a signal that engages the executive selection mechanism; and that the latency effect [semantic interference] is due, in whole or in part, to the time needed for this mechanism to come on-line and/or affect the outcome of the competition" (p. 220). However, the extent to which top-down mechanisms are implicated in semantic interference is still matter of debate and further studies may shed light on their role in this phenomenon.

On the other hand, correlational analysis showed a significant correlation between FI/FD cognitive styles and semantic interference in the continuous picture naming, but not in the semantic probe. Additionally, results did not report a significant correlation of FI/FD cognitive styles and interference in the Stroop task. To our knowledge, to date no one has published a relation between cognitive styles and semantic interference in a naming task.

In conclusion, even though FI/FD cognitive styles have been reported to correlate with several cognitive processes such as visuo-spatial abilities (Mitolo et al. 2015; Boccia et al. 2016), learning abilities (Ipek 2011; Nozari and Siamian 2015), and working memory capacity (Rittschof 2010; see Evans et al. 2013 for a review), few is known about the role of these cognitive styles in speech production. The present work brought the evidence of a relationship between cognitive styles and lexical retrieval, when this occur in an interfering context, shedding the basis for further studies.

Chapter 3: Longevity and resilience of cumulative semantic interference in picture naming: Implications for models of word production

The *semantic interference (SI)* effect refers to a worse performance when naming semantically related items. In picture naming, a target word is activated along with semantically related alternatives (competitors). This means that retrieval of the target item becomes more difficult in the presence of semantically related distractors, with slower naming latencies and increased errors. In the literature, two main hypotheses account for this effect. The *residual activation hypothesis* assumes that lexical selection occurs when the activation of the target word surpasses the activation of competitors by a given amount. According to this hypothesis, presentations of semantically related items makes naming more difficult because, although activation slowly returns to baseline after selection, residual activation of the distractors makes more difficult for the target to reach the required difference in activation. According to this hypothesis, semantic interference should dissipate over time if no other semantically related item is presented. Moreover, interference should not grow indefinitely with number of related items because what slow down selection is the difference in activation with the competitor with the highest activation. This will increase with a presentation of a few competitors because they will mutually reinforce their activation. After a point, however, adding more exemplars will not matter. The *incremental learning hypothesis*, instead, assumes that selection is based on a competition processes by which certain connections are strengthened and others weakened. Presentations of semantically related items makes naming more difficult because the semantic-lexical connection of the target will have been weakened and those of competitors strengthened. This hypothesis predicts that interference should not spontaneously dissipate over-time (semantic networks are stable if new related items are not presented), but also that interference should continue to grow with number of distractors. We tested these predictions in two related experiments. Following the prediction of the residual activation hypothesis we find that activation dissipates after an unfilled delay and that the strength of interference tapers off after presentation of distractors.

Introduction

The semantic interference (SI) effect refers to the finding that speed of naming generally slows down when retrieving a series of semantically related words (Damian et al. 2001; Belke et al. 2005; Oppenheim et al. 2010; Navarrete et al. 2012). SI effects are typically induced when repeatedly naming sets of semantically related (e.g. dog, cat etc.) versus unrelated pictures (*cyclic blocking picture naming;* for review, Belke and Stielow 2013) or naming sets of semantically related pictures interspersed with unrelated pictures (*continuous picture naming;* see Howard et al. 2006). The effects of SI are conceptualized in activation based traditional network models of lexical access (e.g. Levelt et al. 1999). These are hierarchical network of nodes that represent conceptual, syntactic, and phonological information (Friedmann et al. 2013), and the retrieval or *activation* of one node causes cascading activation down the hierarchy (Collins and Loftus 1975; Dell 1986; Roelofs 1992a; Roelofs 1997; Levelt et al. 1999; Foygel 2000; Chen and Mirman 2012). Cumulative SI effects are typically conceived as resulting from the relatively persistent activation of previously selected information, which can slow down selection of a new target word (*residual activation hypothesis*). By contrast, other models (see Howard et al. 2006; Oppenheim et al. 2010) suggest that SI may be more attributable to long-lasting changes, such as the persistent strengthening of mapping from semantic to lexical entries (*incremental learning hypothesis).* However, the time frame (or longevity) of these mechanisms (residual activation and incremental learning) and hence the interference is yet to be established. Here, we carried out two experiments to test predictions from these hypotheses and reach a better understanding of the mechanisms that underlie SI and, more generally, lexical retrieval.

Current lexical models can be contrasted along a number of parameters which can be combined in different ways but with some combination of parameters be needed for making some models viable.

1) Activation during selection vs activation after selection. First of all, note that all models have to explain why the presentation of semantically related primes produces short-lived facilitation and then, more durable interference (Wheeldon and Monsell 1994). This can be explained by two mechanisms a) shared activation among semantically related words during selection; b) inhibition of semantic competitors after selection (see Navarrete et al. 2012) for a recent example with cyclic naming where strong semantic similarity between members of the semantic set create facilitation, but this is eliminated by inserting filler items). Then interference effects can be explained using different model characteristics.

2) A differential or an absolute activation threshold. A differential threshold means that the activation of the target needs to surpass that of noise or possible competitors by a given amount (for models of this type see Wheeldon and Monsell 1994; Roelofs 1997; Levelt et al. 1999). An absolute threshold means that to be selected a word needs to reach a given level irrespective of that of possible competitors (see Dell et al. 1997, but also Luce 1959 for such models; see also the early Logogen model of Morton 1970). Models with an absolute activation threshold can explain repetition priming and positive effect of semantic priming (the word starts from a higher activation level and required level for selection is reached more easily), but not effects of semantic interference without additional mechanisms. Note that absolute threshold models cannot explain differences in RTs; they can still explain more errors after a semantic prime, because a distractor may reach activation sooner than the target.
3) Lateral inhibition vs resetting of connections. If a differential threshold is not assumed, to explain interference, you need to add some mechanisms which would reduce the activation of competitors during lexical selection and consequently make activation of these competitors more difficult in future trials when they become targets. One such mechanisms is lateral inhibition where words have inhibitory connections with their semantic coordinate so that activating a target means inhibiting distractors (see for example Howard et al. 2006). Another mechanism is an incremental learning mechanism which reset semantic to lexical connections after naming so that connections between semantic features and the target are strengthened and those between semantic features and competitors are weakened (see Oppenheim et al. 2010).
4) Activation levels/connections change only as a function of experience (both Howard et al. 2006; Oppenheim et al. 2010) or also as a function of passage of time (see earlier connectionist models, Roelofs 1992b; Roelofs 1992a; Dell et al. 1997; Levelt et al. 1999; Foygel 2000). In the first case the presentation of related items is necessary to change the balance of activation in the lexical network in the second case activation returns spontaneously to base-line.

As mentioned, these model characteristics are partly independent of one another, but for our purposes we can contrast two broad types of models.

1) The Residual activation hypothesis refers to models where activation threshold can be either a) differential or b) absolute and combined with lateral inhibition. In these models, activation is an integrated property of the lexicon: if the activation of a unit increases it means that the activation of other units decreases. This means that

activation has to slowly return to baseline even if no semantically related word is presented to avoid excessive activation hampering discrimination between units. This also means that interference cannot grow indefinitely. Presentation of more potential competitors only contributes to background noise. When this is already high presentation of a further competitor will have a progressively more limited effect. These models are good at explain existing results showing effects of the inter-stimulus-interval (ISI) and contrasts between early facilitation and later interference.

2) Incremental learning hypothesis refers to models which include a more permanent modification of connections following the experience. In these models, lexical selection should not be modified by passage of time alone. To explain her results (that semantic interference dissipates with longer lags), Schnur (2014) assume that changes in connection strength dissipate over time but this is really contrary to the spirit of incremental learning models.

Following some models of word production, lexical retrieval occurs when the target unit reaches an activation threshold which surpasses that of noise and/or possible competitors (Levelt et al. 1999; Riesenhuber and Poggio 1999; Oster et al. 2009). In picture naming, a target is activated along with other semantically related alternatives (competitors). Previous selection of these competitors will make target selection more difficult because activation of the competitors will persist for a while making more difficult to distinguish target activation from background noise (for models were activation is short-lived see Anderson, 1976; Collins and Loftus 1975; Bock and Griffin 2000). Alternatively, other computational models (Howard et al. 2006; Oppenheim et al. 2010) attribute the cumulative semantic interference to permanent strengthening of the connections from semantics to lexical units. Howard et al. (2006), posit that SI is composed of three key components a) *shared activation* amongst semantically related conceptual/lexical representations (Collins and Loftus 1975; McNamara 1992); b) *priming* (or strengthening) connections between semantic and lexical representation, after a lexical representation has been selected, to optimize future target re-selection; and, c) *competition*, which can delay selection via lateral inhibition (McNamara 1992; Stemberger, 1985) or decision criterion (e.g., activity relative to other representations; Luce choice ratio, Luce, 1959; Meyer and Schvaneveldt 1971; Levelt et al. 1999; Roelofs 1999). Particularly, Howard suggests that priming plays a crucial role in amplifying this competition. Indeed, when a target is correctly retrieved, its semantic/lexical connections are strengthened, making it a strong competitor and thus slowing the successive retrieval of a semantically related word. Consistent with Oppenheim et al. (2010) also hypothesize that SI occurs as a consequence of the adjustment of semantic to lexical connections. However, they do not share Howard et al. (2006)'s hypothesis that slower naming of a following related items are exclusively attributed to a process of competition. Instead, they posited that those connections that are not used, but semantically related to the named picture (e.g. cat, mouse) are weakened-or inhibited. Despite the differences, both models converge on the assumption that SI arises as a result of changes in the mapping of the conceptual and lexical representations. These changes are persistent and do not decay as a function of time, thus are insensitive to unrelated trials. Wheeldon and Monsell (1994) provided early evidence for the existence of semantic interference effects in picture naming. They showed that naming a picture (e.g. shark) slowed down after producing a related word elicited by a definition (e.g., "The largest creature that swim in the sea"; Answer: whale). This effect was modulated by inter- stimulus interval. It was absent when the target immediately followed the prime (lag zero), it was present when two unrelated trials intervened between the prime and the target (lag 2; about 1 sec), but it dissipated after a longer delay of several minutes, (38-100 lag; approximately four to eight minutes; but errors increased in all conditions). To reconcile their results with other reports of facilitatory effects of semantic primes, the authors invoked two mechanisms: a) a very short-lived facilitation due to shared semantic features between prime and target, which counteracts any negative effect of prime competition thus explaining no interference effect at lag zero; and b) a more long-lasting inhibition due to the raised activation of a competitor, which is responsible for the interference effect seen after a longer delay, but which also dissipates in due time. Although Wheeldon and Monsell's experiments can be interpreted using different models, they show that changes in lexical level of activation/lexical connections reset after a period of time when semantically related items are not presented.

More recently, the effect of inter-stimulus interval on semantic interference has been investigated using continuous naming and cyclic naming paradigms. Howard et al. (2006) used a continuous picture naming paradigm where participants name a sequence of pictures and embedded within the sequence there are sets of semantically related items (usually five). They found that participants' naming speed decreased with presentation of each new category member (*cumulative semantic interference*) in the order of roughly 30ms (see also Alario and Martín 2010; Navarrete et al. 2010). Importantly, cumulative semantic interference was not affected by the number of intervening items (lag from 2 to 8). This is contrary to the residual activation hypothesis. However, in a following study using a continuous picture naming paradigm Schnur (2014) found that modifying the ISI between items did not change the magnitude of the SI effect but changing the number of items intervening from one item in the set to the next did. The semantic interference effect dissipated when related items were separated by larger gaps (20, 30, 40, 50 intervening items; experiment 2a) relative to smaller gaps (8, 10, 12, 14 intervening items; experiment 2b). Schnur et al. (2006) also assessed the effect of stimulus-response interval (SRI) using a cyclic blocking paradigm -where there is normally a gradual slowing of responses across cycle. She found no change in the magnitude of the interference effect when the ISI was varied from short (1s) to long (5s). They concluded that SI relies on relatively long-term changes, as opposed to transient changes in activity levels. One can note, however, that with cyclic blocking there is an empty gap between presentation of one item and the next, in contrast with the continuous naming paradigm gaps are filled by presentation of other (unrelated) pictures. This leaves open the possibility of a 'mixed model' where activation dissipates as a function of time but this dissipation is accelerated by the presentation of intervening pictures which contribute to reset activation levels in the lexicon even if less drastically than semantically related pictures. There is some evidence in the literature that interference effects are modulated by inter- stimulus-interval (ISI), but this evidence is relative limited. Specially, there is limited evidence of the effects of unfilled ISI rather than number of lags. Schnur (2014) finds no effect of longer ISI in continuous picture naming, but she only extends the time interval from one picture to the next from 750ms to 5 seconds. Here we want to provide more evidence that passage of time alone can modulate lexical activation by showing that even when interference has reached a high level in a continuous picture naming task, it can return to base-line after a few minutes of rest. Furthermore, we want to show some novel evidence that cumulative interference effect has a clear upper-boundary and does not grow beyond five-six related items.

We carried out two experiments to assess the persistence of cumulative semantic interference and the mechanisms underlying this phenomenon. In a first experiment, we tested whether cumulative semantic interference continues to grow in an extended sequence of related items (e.g. over the default five positions described in the literature). According to the incremental learning hypothesis SI accumulates with relevant experience and therefore should continue grow with presentation of more exemplars (see Oppenheim et al. 2010), according to the residual activation hypothesis it should plateau consistent with a plateau of background noise with more exemplars. In a second experiment, we assessed whether the SI resets after an unfilled delay during which participants are not involved in other tasks. In this experiment, a 5-minute interval intervened between two parallel versions of continuous picture naming task. This break should be sufficient to observe a return of cumulative semantic interference at baseline level (see Wheeldon and Monsell 1994), if activation decays spontaneously as predicted by the residual activation hypothesis but not if changes in lexical connection are more permanent as predicted by the incremental learning hypothesis. To anticipate results, our findings will be consistent with the residual activation hypothesis.

Experiment 1: Semantic interference over a larger set of items

Experiment 1 investigated the duration of cumulative semantic interference in picture naming over the five positions commonly assessed in the literature (Howard et al. 2006; Navarrete et al. 2010). Participants performed a variant of the continuous picture-naming task in which the sequence of related items was extended over the default five positions.

Method

Participants

A total of 23 participants were recruited (age mean = 25 SD = 5). They were all undergraduate students at Aston University and participated in exchange for research credits. All were English native speakers, they claimed to have normal or corrected to normal vision, were right-handed, and had no language impairments. Participants were naïve to the purpose of the study.

Materials

We generated a list of picture stimuli that consisted of 165 coloured pictures (720 x 540 pixel dimensions) drawn from a variety of sources (Viggiano et al. 2004; Adlington et al. 2009; Brodeur et al. 2010; Moreno-Martínez and Montoro 2012). The set comprised of experimental pictures (N=108) and non-experimental (“filler”) pictures (N=57) (*Appendix 13*). The experimental pictures contained 9 different members drawn from each of the 12 semantic categories. The presentation sequence of picture stimuli was controlled as follows. The first and last five items were filler items. Each category was presented in a sequence that separated category members by 2, 4, 6, or 8 intervening items (or lag). Intervening items were semantically unrelated, consisting of filler items or items from other semantic categories. Across participants, categories were inserted into one of the 23 possible lag order sequences, and members of the same semantic category were randomly inserted to an ordinal position (1 to 9).

Procedure

Participants were instructed to name the pictures as fast and as accurately as possible. They were reminded to name the pictures using bare nouns, and sub-ordinate labels (e.g., a correct response to water-lilly is “water-lilly” or “lilly” but not “flower”). Participants were also asked to avoid making unnecessary noises (e.g., coughing, sneezing) to prevent false triggering of the voice key. Each naming trial started with presentation of a fixation cross for 1000ms followed by a blank screen for 250ms. Stimuli were then presented and remained on the screen for 2500ms until the participant made a verbal response. The naming trial finished with a blank screen presented for 500ms and then the next trial started. Accuracy of naming responses was judged offline on the basis of voice recordings. Responses were defined as errors whether the name was incorrect or no response was given. Synonyms (e.g., “mule” instead of “donkey”) were judged correct. The experiment was run using E-Prime 2 Software. Vocal responses were recorded using a Sony ICDPX333.CE7 digital voice recorder. Naming latencies were registered using a voice-key (PST Serial Response Box) and a Sony ECM-MS967 microphone.

Analysis

Reaction Times: Omitted or incorrect responses were excluded from the analyses. Latencies below 250ms (false trigger; mean 1%) and above 3 standard deviation (outliers; mean 2%) of the subject overall mean were also removed. Remaining data were fitted with linear and nonlinear mixed effect modelling (Baayen et al. 2008; Bates et al. 2015b; Bates et al. 2015a; see also Snijders and Bosker, 2011). In this kind of modelling the dependent variable is thought to be the sum of both fixed and random effects, with the latter contributing only to the covariance of data. Mixed modelling relies on single trial data rather than averages by subjects (or other factors). In this way, random and fixed effects are explicitly controlled.

Mixed effect modelling has been used to analyse results from a continuous picture naming paradigm (Costa et al. 2005; Alario and Martín 2010; Runnqvist et al. 2012; Mulatti et al. 2014). Howard et al. (2006) noted that the experimental structure of continuous picture naming minimizes but does not eliminate a confounding between ordinal position in a semantic set and absolute serial position in the experiment (1-165). In the literature, this problem has been addressed using mixed models and absolute serial position as a fixed factor along with ordinal semantic position (Alario and Martín 2010; Mulatti et al. 2014).

For the present study both linear and nonlinear mixed models were built by means of “lme4” package (Bates et al. 2015b; Bates et al. 2015a) implemented in R (R Development Core Team, 2008). Statistics for each model were computed by using “lmertest” package for R (Schaalje et al. 1997). Furthermore, for reaction times, Kenward-Rogers approximation for degrees of freedom was computed. This method works reasonably well with complicated covariance structures when sample sizes range from moderate to small (Schaalje et al. 1997).

A first model was created in order to replicate Howard's results (Howard et al. 2006), namely a main effect of ordinal positions, which was unrelated to lags. In such a model, ordinal positions and lags were conceived as fixed effects.

Then, other three main models were created: a) a linear model which assumes a linear increase of reaction times as a function of ordinal positions. In this model, SI was supposed to grow unabated across the 9 positions in the semantic sets; b) a logarithmic model, levelling out of RTs with a stabilization in the last ordinal positions; c) a quadratic model which assumes that RTs peak in a given point and then decrease. To address a confounding between the semantic ordinal position and absolute serial position (see Alario and Martín 2010; Mulatti et al. 2014), for each model, we used serial position (1-165) as a fixed factor along with ordinal position. For all our models, participants and categories were conceived as random effects.

We further explored the size of SI by computing two separate cumulative interference indices for the first and second subsets in the series of semantically related items. The subset-1 SI index was estimated as the difference between position 3+4 and positions 1+2. The subset-2 SI index was estimated as the difference between positions 8+9 and positions 6+7. These indices were submitted to a repeated measures ANOVA using participants and categories as random factors (F1 and F2).

Errors. The same analyses were carried out in terms of errors. However, mixed effects models were assessed by means of "glmer" command ("lmer4" package). This method was used to model binary outcome variables which are modelled as a combination of the predictor variables when data are clustered or there are both fixed and random effects (Agresti, 2013; Quené and van den Bergh 2008). Consistently with reaction times analyses, the same linear and nonlinear (logarithmic and quadratic) models were created in order to investigate any increase or decrease of correct responses as a function of ordinal positions. Position and categories were inserted into the model as random effects.

Results

Reaction times: Our first model replicated Howard's results, that is a main effect of Ordinal position ($F_{1,1645}$= 7.27, p = .007), but neither a main effect of Lag ($F_{1,1645}$=1.77, p= .18) nor an Ordinal position by Lag interaction ($F_{1,1645}$= .98, p= .32). Results from the other three models are shown in Figure 11. The linear model reported a significant effect of Ordinal position ($F_{1,1841}$=8.56, p= .003), but neither a significant effect of Serial position ($F_{1,1841}$= .70, p= .40) nor an Ordinal position by Serial position interaction ($F_{1,1841}$= .36, p= .54). The reaction times distribution, however, was not perfectly linear, but, instead, showed a logarithmic or quadratic component. In fact, there was a significant effect of ordinal position in both the logarithmic ($F_{1,1841}$= 7.65, p= .005) and quadratic model ($F_{1,1841}$= 7.75, p= .005), but no effect of serial position in either case (see Table 1). Consistent with these results, the interference index was positive (mean= 48) for the first subset of items but slightly negative (mean= -20) for the second subset ($F1_{1,22}$= 5.23, p= .03, η^2_p= .19; $F2_{1,11}$= 2.45, p= .14, η^2_p= .18).

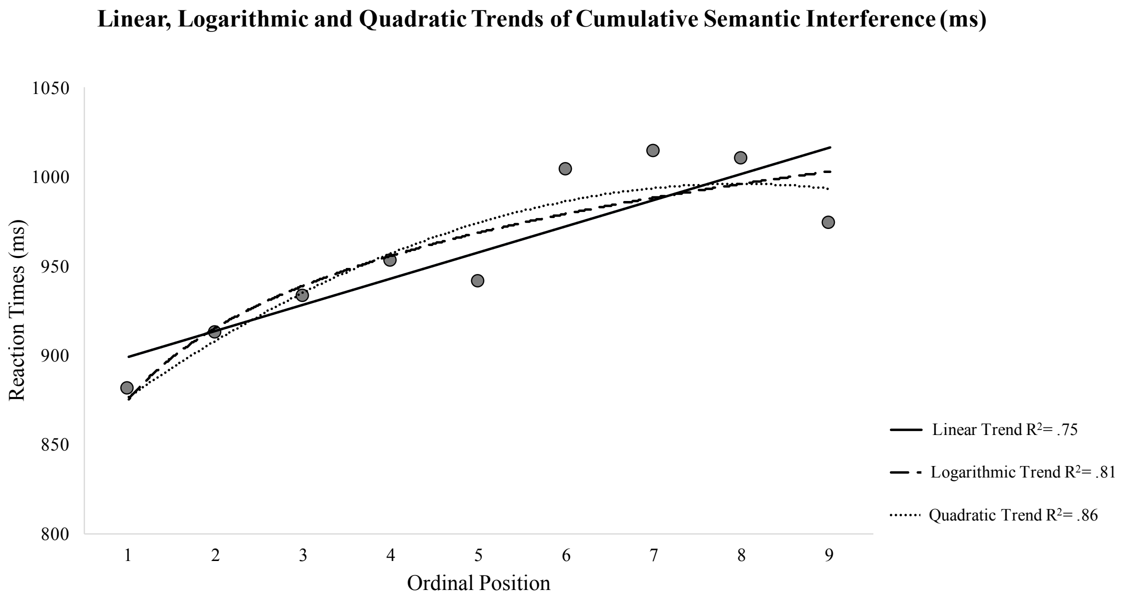

Figure 11*. Cumulative increase of naming latencies across ordinal positions. Each line in the figure depicts the three main different trends (linear, logarithmic and quadratic). The R^2 have been reported.*

Table 1. *Statistics of the 4 models examining RTs*

Model	Fixed Factor	Fixed Factor Statistics		Model's Statistics			
		F	p	AIC	BIC	R^2_M	R^2_c
Howard's model	Ordinal Position	7.27	.007	24060	24098	.009	.21
	Lag	1.77	.18				
	Ordinal Position x Lag	.98	.32				
Linear	Ordinal Position	8.56	.003	26852	26891	.01	.22
	Serial Position	.70	.40				
	Ordinal Position x Serial Position	.36	.54				
Logarithmic	Ordinal Position	7.65	.005	26845	26883	.01	.22
	Serial Position	.09	.76				
	Ordinal Position x Serial Position	.0006	.98				
Quadratic	Ordinal Position	7.75	.005	26867	26906	.01	.22
	Serial Position	1.79	.54				
	Ordinal Position x Serial Position	.88	.34				

Errors. Differently from reaction times none of created models reported a significant effect of both Ordinal position, and of the absolute serial position (Figure 12; Table 2).

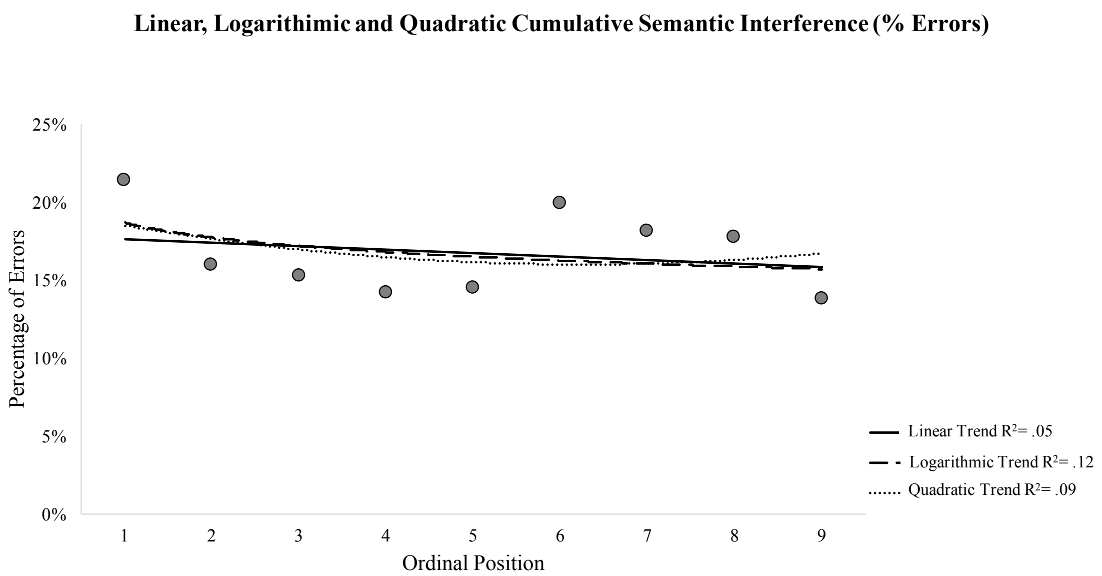

Figure 12*. Cumulative increase of errors across ordinal positions. Each line in the figure depicts the three main different trends (linear, logarithmic and quadratic). The equation of linear trend as well as the R^2 have been reported.*

Table 2. *Statistics of the 4 models examining RTs*

Model	Fixed Factor	Fixed Factor Statistics		Model's Statistics			
		X^2	p	AIC	BIC	R^2_M	R^2_c
Howard's model	Ordinal Position	1.06	.30	1788	1822	.001	.23
	Lag	.34	.54				
	Ordinal Position x Lag	.83	.36				
Linear	Ordinal Position	1.96	.23	2028	2063	.001	.24
	Serial Position	.07	.44				
	Ordinal Position x Serial Position	.51	.47				
Logarithmic	Ordinal Position	1.74	.35	2027	2062	.002	.24
	Serial Position	.92	.34				
	Ordinal Position x Serial Position	.32	.56				
Quadratic	Ordinal Position	1.95	.12	2028	2063	.001	.24
	Serial Position	.007	.38				
	Ordinal Position x Serial Position	.69	.35				

Discussion

We investigated to what extent semantic interference increases across an extended set of nine semantically related items. We found that speed latencies increased as a function of ordinal positions, but logarithmic and quadratic model best fitted with the data indicating a tapering off of the effect (interference stopped increasing after 5/6 related items). These results are consistent with the residual activation account which see semantic interference as a phenomenon with an upper bound, linked to the differential level of activation present between a target and possible competitors.

Experiment 2: Semantic interference after an unfilled delay

Experiment 1 has shown that SI does not continue to grow beyond a certain number of items (five or six). Experiment 2 wanted to investigate whether interference dissipate after an unfilled delay and RTs return to baseline. Participants performed two parallel versions of the continuous picture naming tasks that were separated by a 5-minute interval. Both versions differed only in terms of category exemplars.

Method

Participants

Twenty-three right-handed participants were recruited from Aston University community (mean age 32, SD 12). All claimed to have normal or corrected to normal vision and had no language impairments. Participants were naïve to the purpose of the study and were paid for their participation. Each participant participated to two testing session one week apart.

Materials

We generated a set of picture stimuli that consisted of 285 coloured pictures (720 x 540 pixel dimensions) drawn to the same sources of first experiment. The set comprised of 240 experimental pictures and 45 "fillers" (*Appendix 14*). Experimental stimuli were grouped into 24 semantic categories, with 10 items in each. Pictures were then separated to create two lists of 165 stimuli each (hereafter referred to as list A and B). Each list contained filler items and 5 different members for each of the 24 semantic categories. For both lists, presentation of the stimuli followed Howard et al. (2006): the first and last five items were filler items; category members were separated by 2, 4, 6, or 8 intervening items (lag), which were either fillers or pictures from other categories; each category was inserted into one of the 24 possible lag order sequences and category members were assigned to an ordinal position (i.e., 1 to 5) in the lag sequence. In the literature, this structure is well known to induce a linear increase of both reaction times (Howard et al. 2006) and errors (Navarrete et al. 2010) as a function of ordinal positions (cumulative semantic interference). To make sure that positional effects were not confounded with lexical variables, in both lists, picture names were matched across ordinal positions for word frequency, word length (CELEX Database; Baayen et al. 1995) and age of acquisition (Kuperman et al. 2012) (*Appendix 15*). A pilot study confirmed that in both lists naming latencies increased with each semantically related picture named in the order of 35ms, consistent with previous studies (Howard et al. 2006; Navarrete et al. 2010).

Procedure

The two lists were presented back-to-back and separated by 5 minutes unfilled gap during which participants were instructed just to rest. The two possible list orders (A-B; B-A) were counterbalanced across two participant groups and testing sessions. Participants were assigned randomly to the two groups. For other details the procedure was the same as the Experiment 1.

Analysis

Reaction Times. Omitted or incorrect responses were excluded from the analyses. Latencies below 250ms (false trigger; mean 5%) and above 3 standard deviation (outliers;

mean 2%) from the subject overall mean were also removed. The remaining data were log transformed to reduce skewness and approach a normal distribution and were submitted to linear mixed models, with list (1 and 2, respectively before and after 5-minute break) and position (1 to 5) as fixed factors and participants and categories as random factors. We wanted to assess whether SI persisted, changed or reset to a baseline level after a given amount of time. To further explore these possibilities, a cumulative semantic interference index was estimated for both lists and submitted to a repeated measure ANOVA. This index was computed by averaging the latencies in the first two positions (hereafter "1+2") and the last two positions (hereafter "4+5") and by calculating the difference between them ((4+5)-(1+2)). This ANOVA was carried out using participants and categories as random effects (F1 and F2 respectively; Clark 1973; Brysbaert 2007).

Finally, we assessed the effect of list only for the first session. The rational was that sessions could gloss over the effect of list. Specifically, when List 1 was tested first in Session 1 and second in Session 2, repetition priming from Session 1 might abolish any extra interference that might otherwise be there for the second list tested in the second session.

Errors. Cumulative semantic interference has also been described in terms of errors (see Navarrete et al. 2010). Thus, the same analyses were also carried out on errors.

Results

Reaction times. Results are shown in Figure 13 and Table 3. The first linear model showed a cumulative increase of reaction times as a function of the ordinal position ($F_{1,9332}$= 12.50, $p < .001$). However, semantic interference did not diverge for List 1 and 2 ($F_{1,9332}$= .64, p = .42). There was a similar significant linear component for List 1 ($F_{1,4642}$= 44.98, $p < .001$) and List 2 ($F_{1,4653}$= 30.05, $p < .001$), with a gradient of 18ms/item in the former list and 14ms/item in the latter. The cumulative semantic interference index was slightly higher in List 1 (mean= 50) than List 2 (mean= 42), but this trend was not significant as shown in the repeated measure ANOVA ($F1_{1,22}$= 1.25, p= .27, η^2_p = .05; $F2_{1,23}$= 1.37, p= .25, η^2_p = .05). Finally, the analysis carried out only for the first session confirmed the previous results, namely a significant increase of the naming latencies across the ordinal positions ($F_{1,4625}$= 4.52, p = .03), no differences in terms of overall latencies ($F_{1,4625}$= .03, p = .84) and semantic interference for List 1 and List 2 ($F_{1,4625}$= .02, p = .87).

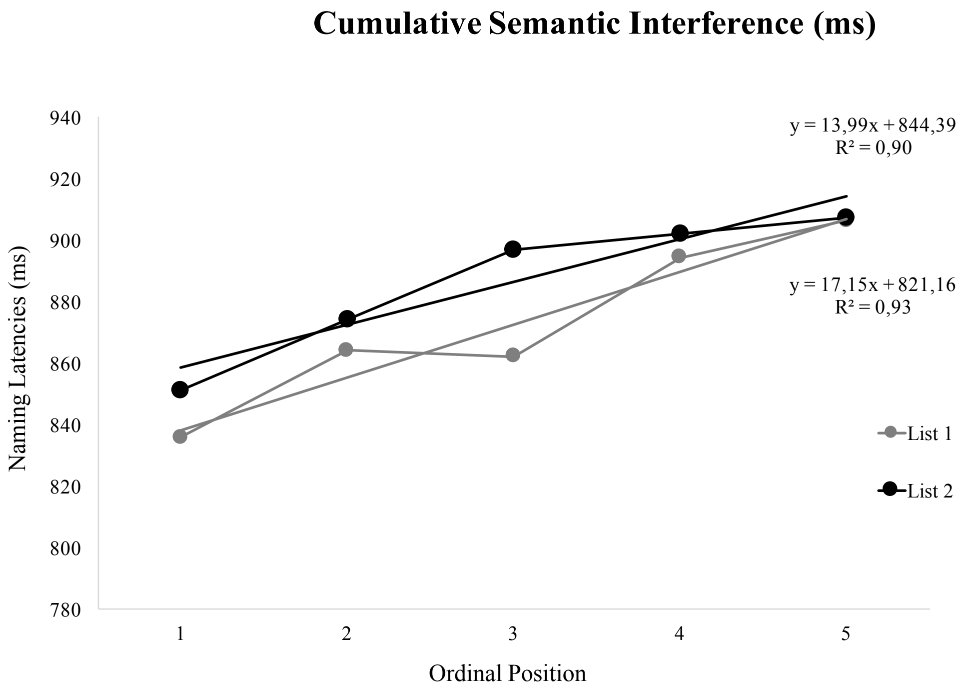

Figure 13. *Cumulative increase of naming latencies across ordinal positions separately for list 1 and 2. Continuous lines depict the linear trend. The equation of linear trend as well as the R^2 have been reported.*

Table 3. *Statistics of the 4 models examining RTs*

Model	Fixed Factor	Fixed Factor Statistics		Model's Statistics			
		F	p	AIC	BIC	R^2_M	R^2_c
Linear	Ordinal Position	12.50	.001	2837	2887	.007	.14
	List	4.03	.04				
	Ordinal Position x List	.64	.42				
LinearSession1	Ordinal Position	4.52	.03	1502	1547	.007	.16
	List	.03	.84				
	Ordinal Position x List	.02	.87				

Errors. Results are reported in Figure 14 and Table 4. Linear mixed models showed a significant main effect of Ordinal position ($X^2_{(1)}$= 4.03, p= .04), but no significant effect of List nor a significant List by Ordinal position interaction. A linear component was significant for both lists (List 1, $X^2_{(1)}$= 11.75, p < .001; List 2, $X^2_{(1)}$= 4.03, p= .04). For both lists this linear trend was mainly due to difference between errors in the first and fifth position rather than their gradually increase. Consistently with reaction times analysis, errors also showed a higher SI index for List 1 as compared to List 2, but this difference was not significant ($F1_{1,22}$= 1.41, p= .24, η^2_p = .06; $F2_{1,23}$= .31, p= .57, η^2_p = .01). These results were replicated when the same analyses were performed on data in Session 1

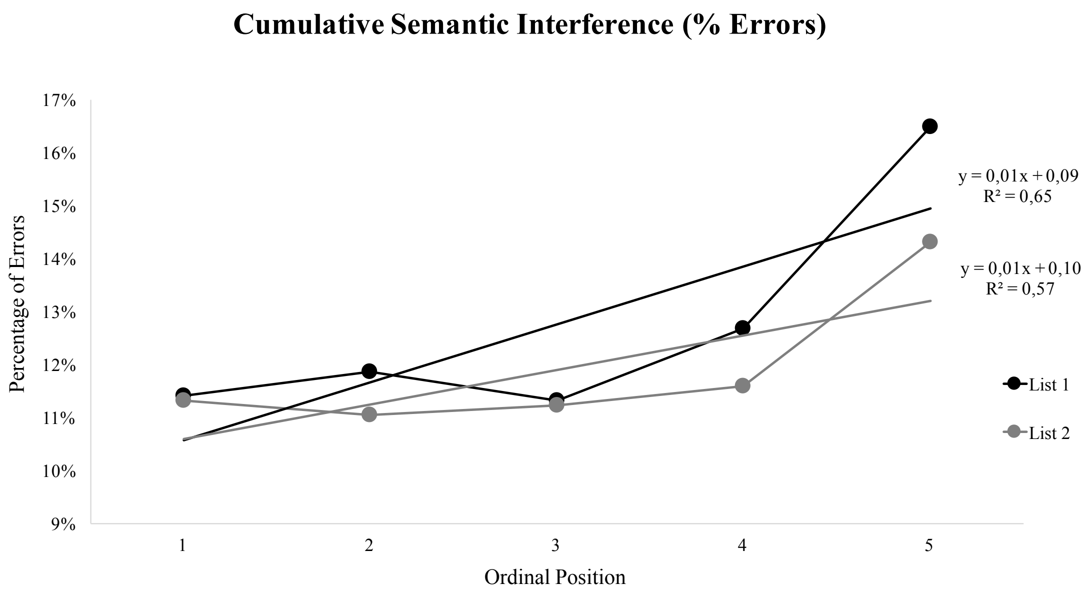

Figure 14. *Rate of errors across ordinal positions for list 1 and 2. Continuous lines depict the linear trend. The equation of linear trend as well as the R^2 have been reported.*

Table 4. *Statistics of the 4 models examining RTs*

Model	Fixed Factor	Fixed Factor Statistics		Model's Statistics			
		X^2	p	AIC	BIC	R^2_M	R^2_c
Linear	Ordinal Position	4.03	.04	5277	5320	.004	.39
	List	.02	.87				
	Ordinal Position x List	.64	.42				
Linear Session1	Ordinal Position	6.1	.01	2793	2833	.008	.38
	List	.06	.80				
	Ordinal Position x List	2.94	.08				

Discussion

We investigated if semantic interference could persist after a period of 5mins using two parallel versions of the continuous picture naming task. We found that semantic interference completely dissipated after the 5-minute time interval and naming latencies returned to baseline. These results are consistent with the study of Schnur (2014) in which semantic interference was shown to decrease as a function of intervening items (lag) in continuous picture naming, and work with other tasks which show that with a similar time interval (approximately of 4 minutes) semantic interference regresses to baseline levels (Wheeldon and Monsell 1994; Damian and Als 2005). These results are consistent with the residual activation account which sees semantic interference as a transient phenomenon which dissipates over time.

General Discussion

The present study aimed at investigating the time frame (or longevity) of cumulative semantic interference. In the context of this study we took into account two main models as theoretical frameworks. On the one hand, SI has been conceived as resulting from a temporary activation of a previously selected word (residual activation account), which lasts for only a short interval. On the other hand, SI reflects persistent changes in the connections between conceptual and lexical entries (incremental learning account), which do not dissipate as a function of time. These approaches suggest two distinct predictions about the length of SI, respectively its decrease (residual activation account) or its persistence (incremental learning). We tested these predictions by means of two experiments in which: a) the sequence of related items in a continuous picture naming task was extended over the default number (Experiment 1); b) two parallel continuous picture naming lists were interspersed by a time interval of five minutes. During this time, semantic/lexical entries were not accessed (Experiment 2). I find that activation dissipates after an unfilled delay and that the strength of interference tapers off after presentation of distractors. Results, were inconsistent with the incremental learning approach, showing that mechanisms underlie semantic interference (e.g. activation or inhibition) are time-bound. Accordingly, semantic interference cannot increase unbated, but would rather descrease after a given amount of time.

Chapter 4: Different lexical mechanisms in the emergence of word retrieval deficits: Evidence from aphasia

Lexical retrieval may involve three types of mechanisms (bottom-up mechanisms): *activation*, which would activate a cohort of words whose semantic specification is partly overlapping with the target; *lateral inhibition*, which would suppress semantically related competitors; and *priming*, which would facilitate the future selection of a previous retrieved word. These bottom-up mechanisms have been conceived to contribute differently to slowing lexical retrieval when naming occurs amid semantically related objects (semantic context): *semantic interference effect*. On the other hand, when the lexical system experiences an exceeding interference, it is possible that *executive control mechanisms* (top-down mechanisms) modulate lexical access by biasing activation or inhibitory mechanisms, thus promoting the target response. Top-down mechanisms require time to build up and therefore may have a stronger effect on slower than on faster responses. Given such complexity, a damage to bottom-up and/or top-down mechanisms would lead to different predictions about the occurrence of specific patterns of deficits in lexical retrieval, especially when selection occurs in a semantic context. In the present study, we investigated these predictions in different experiments by comparing the performance of aphasic patients and healthy individuals in naming (continuous picture naming task and cyclic blocking naming task) and recognition tasks (semantic probe) inducing semantic interference and, finally, in a Stroop task. Our results showed that in naming tasks a subset of patients (group 1) demonstrated an exaggerated effect of interference in terms of reaction times and omission errors, but not in terms of coordinate and perseveration errors. A group of patients, instead (group 2), showed high interference in terms of coordinate and perseveration errors, but not for reaction times and omissions. Furthermore, in the second group, perseverations decreased as a function of time since the occurrence of the perseverated item. Performance of these groups did not differ in both the semantic probe and the Stroop task. We explain group 1 deficits as spared lateral inhibition, but a weaker activation of target representations, leading to a pathological refractory state. In these patients, refractoriness hampers target word to reach the activation threshold in order to be named. We explain group 2 deficits as a damage of inhibition mechanisms internal to lexicon, which results in an exceeding activation of semantically related competitors. Our study gives an important contribution about the extent to which specific patterns of lexical retrieval deficits may be ascribable to a damage of one or more lexical mechanisms and sheds light on the mechanisms underlying normal lexical retrieval.

Introduction

Lexical retrieval is a central process in speech production, in which a target word is selected as per the intended message of the speaker, such as when naming a picture. As we described in the general introduction, current models conceptualise lexical retrieval as being driven by activation (*activation models*; Dell et al. 1997; Roelofs 1997; Dell et al. 1999; Levelt et al. 1999; Foygel 2000), inhibition (*inhibition models*; McClelland and Rumelhart 1981; McClelland and Elman 1986; Harley and MacAndrew 1992; Harley 1993; Chen and Mirman 2012), or priming mechanisms (*incremental learning models*; Howard et al. 2006; Schnur et al. 2006; Navarrete et al. 2010; Oppenheim et al. 2010; Schnur 2014), all of which can be considered to be bottom-up processes, which do not require any form of control from external executive processes.

Bottom-up mechanisms contribute to the selection of a target among different candidates (competitors; see Belke 2017), making word production fast and accurate (Levelt 1989; Harley 1993; Chen and Mirman 2012). However, under certain circumstances (e.g. in controlled experimental conditions; see Rosinski 1977; Belke and Stielow 2013; Crowther and Martin 2014), these mechanisms actually hamper lexical retrieval, especially when it occurs in the midst of semantically related items (semantic context). This effect is known as *semantic interference* (Maess et al. 1994; Damian et al. 2001; Damian and Bowers 2003; Navarrete et al. 2012; Belke and Stielow 2013). Its reduction may rely in part on executive control mechanisms (hereafter top-down mechanisms), which constrain ongoing processing (e.g. biasing activation or inhibitory mechanisms), thereby dampening the interference and facilitating the selection of the target response (Badre et al. 2005; Jefferies and Lambon Ralph 2006; Botvinick 2008; Munakata et al. 2011; Whitney et al. 2011; Krieger-Redwood and Jefferies 2014).

Since both bottom-up and top-down mechanisms play important roles in modulating lexical retrieval, especially in the midst of semantic interference, it is plausible that damage to one or both mechanisms – e.g., after a brain injury – may cause specific deficits in lexical retrieval. Indeed, deficits have been widely documented in aphasic patients (McCarthy and Kartsounis 2000; Wilshire and McCarthy 2002; Schnur et al. 2006; Crutch and Warrington 2007; Hsiao et al. 2009; Mirman et al. 2013; Mirman and Britt 2014), but how top-down and bottom-up mechanisms individually contribute to these deficits remains poorly understood.

Here we use tasks that probe semantic interference effects to shed light on the mechanisms that underlie lexical deficits in aphasia, and we test the different predictions posited by different models of lexical retrieval. In the present study, we aim to answer the following research questions in an aphasic population: a) Do aphasic patients differ in terms of semantic interference? b) Do these differences rely on a damage to one or more of those bottom-up mechanisms (i.e. activation, inhibition and priming)? c) Which mechanism, among activation, inhibition and priming, play a crucial role in the emergence of these differences? d) Do these differences rely on a damage involving both lexical and executive control mechanisms?

Patterns of lexical deficits in aphasia

So far, lexical retrieval may be conceived to be driven by bottom-up mechanisms (i.e. activation, inhibition and priming) and also by top-down mechanisms (i.e. executive control mechanisms). Furthermore, as discussed earlier, different models highlight the extent to which these mechanisms may contribute in modulating lexical selection. Given such a complexity, a damage to one or more of these mechanisms may lead to different patterns of lexical retrieval deficits, especially when selection occurs in the midst of semantically related objects. In the literature, these patterns have been explored in aphasic patients. For example, McCarthy and Kartsounis (2000) studied a patient, FAS, a non-fluent aphasic patient with relative spared abilities of single word production and a quite variable presence of omissions during naming. FAS naming performances were adversely affected by semantic context. Indeed, omissions were higher for blocks of semantically related pictures as compared to unrelated blocks. The authors claimed FAS' omission to arise as a post-selection inhibition process involving both the lexical target node and its neighbours. This prolonged inhibition would induce an abnormal refractory state, that is a delay of the lexical-semantic system to bring back activation to normal level. In other words, the inhibition of semantically related words would make lexical retrieval slower and more prone to omissions (Warrington and Shallice 1979; Warrington and McCarthy 1983, Warrington and Cipollotti 1996; McNeil et al. 1994; Forde and Humphreys 1997; Warrington and Crutch 2004; Forde and Humphreys 2013). The authors stated that "It was as if [in these patients] their semantic systems required longer than normal to recover after activation so as to enable the processing of the next item in a series" (McCarthy and Kartsounis 2000 p. 488).

On the other hand, Cohen and Dehaene (1998) reported their patients to be more prone to an inappropriate repetition when a new response was required (perseveration). The authors found a recency bias, i.e., a previous target word was more likely to be repeated when few items (lag) occurred between the repetition and its source. Cohen and Dehaene stated: ''At any processing level, the probability that an error is a perseveration from a previous trial is a decreasing function of the lag between the two trials considered. This suggests that an exponentially decaying variable, such as an internal level of activation, is responsible for the recurrence of perseverations." (p. 1655).

Further evidence came from Wilshire and McCarthy (2002), who reported the performance of a patient, BM, in a cyclic blocking naming task. BM was unable to produce a response (omission) and sometimes was more prone to semantic substitution when stimuli were provided in semantically related blocks. Conversely, BM performed remarkably better for unrelated blocks. The authors claimed that BM's performances could be reliant on the damage of control mechanisms, external to lexicon, which constrained the retrieval of a target item when competition was higher. A similar conclusion was advanced by Schnur et al. (2006; see also Schnur et al. 2009), who found that semantic errors were higher in Broca's aphasic patients than in non Broca's patients, when stimuli were provided in a semantic context. They claimed for the presence of an extra-lexical control mechanism that comes on-line to bias selection, which might be impaired in Broca's patients.

Despite this evidence, the role of different bottom-up and top-down control mechanisms in the emergence of lexical deficits in aphasia is still unclear. Furthermore, results in aphasic patients are far to show a coherent pattern of results due to variability in patients' performances (Nespoulous 2000; Moreno et al. 2002; Krishnan et al. 2012). For example, some studies (Lambon Ralph et al. 2000; Gotts and Plaut 2002; Hodgson et al. 2003) failed to report semantic interference in aphasic patients. Schnur et al. (2006) reported the performance of two patients showing an inverse behavioural pattern compared to their groups: MO, a Broca's patient, performed as a typical non-Broca patient, producing more errors in unrelated than in related blocks. An inverse pattern was shown by EAC, a non-Broca's patients, who performed within the range of Broca's group, producing more errors when stimuli were semantically related.

Aim and hypothesis

In the present study, we posited that a damage at the level of either bottom-up or top-down mechanisms would lead to differences in terms of the semantic interference size as well as distinct patterns of lexical retrieval deficits in aphasia. These specific patterns rely on the importance that different models attribute to one of the aforementioned mechanisms, namely activation, inhibition, priming, and external control mechanisms. Here, we extensively tested these patterns in different experiments in which we compared the performance of aphasic patients and healthy individuals in several tasks inducing semantic interference in naming (continuous picture naming task, experiment 1; cyclic blocking naming task, experiment 2) and recognition (semantic probe task, experiment 3), and finally compared their overall ability to suppress a dominant response by means of a

Stroop task (experiment 4). Consistently with the different models of lexical retrieval we advanced the following predictions (see Table 5 for a summary):

1. Activation models. Consistently with these models, a high semantic interference, only for naming tasks (continuous picture naming, cyclic blocking naming), in terms of latencies may be expected as the result of an exceeding activation of nodes at the lexical/semantic level. Furthermore, a pattern of deficits, coherent with “too much activation”, would bring to an overall high frequency of *coordinate errors* (e.g. naming a picture of a cat as a dog) and perseverative errors. Additionally, activation models posit that semantic interference may be conceived as an effect of a temporary residual activation of a previous named word, which should impair the name of a semantically related picture and gradually decay as a function of time. Consistently with this idea, coordinate errors and perseveration errors, but not omissions, should linearly increase across the exemplars of a given semantic category in the continuous picture naming or in the homogeneous block in the cyclic blocking naming. Moreover, perseverations should decrease as a function of the number of stimuli intervening between the correct production of a word and its perseverative occurrence.

On the other hand, activation model would ascribe the absence or a low semantic interference in terms of latencies to an “under-activation” of nodes at the lexical/semantic level. In such a case, patients would produce more omission errors rather than coordinate or perseverative errors. Furthermore, since under-activation has been attributed to a loss of concepts or their connections at semantic level (Gainotti et al. 1986; Hillis et al. 1990; Wilshire and McCarthy 2002), low or absent repetition priming would be expected in these patients.

2. Inhibition models. Consistently with these models a high semantic interference, only for naming tasks, in terms of latencies may be expected as the result of an abnormal refractory state, i.e. a delay of the lexical-semantic system to bring back the activation to normal levels (e.g. as a consequence of a weaker boosting activation of the target representations). A pattern of deficits coherent with this condition would bring to a low frequency of coordinate and perseverative errors in naming tasks. Furthermore, refractoriness, posit that after the naming of a picture, the successive retrieval of its semantic neighbours will be temporary hampered. Consequently, one may expect that omissions, but not coordinate or perseveration errors, should increase linearly across exemplars of a given semantic category in the continuous picture naming or in the homogeneous block in the cyclic blocking naming. Furthermore, since refractoriness has been conceived to fade over time, omissions in the continuous picture naming tasks would be affected by the number of intervening items between two members of a given semantic category.

On the other hand, since inhibition models ascribe semantic interference as a by-product of inhibitory mechanisms, a lack of semantic interference in terms of latencies should be ascribable to a lack of inhibition (see Gurd and Oliveira 1996; Gotts and Plaut 2002; Biegler et al. 2008; Arnott et al. 2010). The result is a state of “too much excitation”, similar to that predicted by activation models.

3. Incremental learning models. These models are quite similar to activation/inhibition models. However, they differ in the extent to which the results are attributed to more permanent mechanisms (incremental learning). For example, consistently with Howard et al. (2006), the correct retrieval of a given word results in a strengthening of its semantic to lexical connections (priming), making it a strong competitor and thus slowing the successive retrieval of a semantically related word. As we discussed earlier, priming would play a crucial role in amplifying this competition, so higher or lower semantic interference might be ascribable to differences in terms of priming (see Mulatti et al. 2014 for a similar approach). Furthermore, consistently with the incremental learning models, the exceeding activation or inhibition may not be considered as a temporary, but rather as a persistent phenomenon. Accordingly, the different types of errors discussed above (coordinate, perseverations and omissions) should not decay as a function of time (or lags in the continuous picture naming).

4. External control mechanisms. In naming tasks, patients with a damage to external control mechanisms would perform similarly to those with an exceeding activation, namely higher semantic

interference in terms of both naming latencies and errors (coordinate errors, perseverations and omissions; see Wilshire and McCarthy 2002; Schnur et al. 2006; Schnur et al. 2009). However, since external control mechanisms operate on different levels (lexical and not lexical), patients’ performance should be quite consistent across all the experimental tasks (continuous picture naming, cyclic blocking paradigm, semantic probe or Stroop task). Furthermore, consistently with Shao et al. (2013, 2015), when analysing the size of semantic interference by means of a delta plot, the absence of an executive control inhibition would result in an increase of interference on slower responses (last quantile).

Table 5. *Distinct patterns of performance predicted by each lexical retrieval model*

	Continuous Picture Naming/Cyclic Blocking Naming											Semantic Probe					Stroop Task		
Lexical Retrieval Models	Semantic interference (Naming Latencies)	Repetition Priming	Overall Omission Errors	Overall Coordinate Errors	Overall Perseveration Errors	Omission Errors in Semantic Context (Ordinal Positions or Related Block)	Coordinate Errors in Semantic Context (Ordinal Positions or Related Block)	Perseveration Errors in Semantic Context (Ordinal Position or Related Block)	Decrease of Omissions as a Function of Time Intervals	Decrease of Perseveration Errors as a Function of Time Intervals	Delta Plot and Slope for the Last Quartiles	Semantic Interference No Trials (ms)	Semantic Interference No Trials (Errors)	Semantic Interference Yes Trials (ms)	Semantic Interference Yes Trials (Errors)	Delta Plot and Slope for the Last Quartiles	Stroop Effect (ms)	Stroop Effect (Errors)	Delta Plot and Slope of the Last Quartiles
Activation Models	High	Normal	Normal/Low	High	High	No increase in a semantic context	Increase in a semantic context	Increase in a semantic context	No	Yes	Normal	Normal	Normal	Normal	Normal	Normal	Normal/High	Normal/High	Normal
	Low	Low	High	Low	Low	No influence of semantic context	No influence of semantic context	No influence of semantic context	Omissions are stable across time intervals	No	No Interference across quartiles	Normal	Normal	Normal	Normal	Normal	No	No	No effect across quartiles
Inhibition Models	High	Normal	Normal/High	Low	Low	Increase in a semantic context	No Increase in a semantic context	No Increase in a semantic context	Yes	No	Normal	Normal	Normal	Normal	Normal	Normal	Normal/High	Normal	Normal
	Low	Normal	Normal	High	High	No Increase in a semantic context	Increase in a semantic context	Increase in a semantic context	No	Yes	No/or Low interference across quartiles	Normal	Normal	Normal	Normal	Normal	Normal/Low	Normal/High	Normal
Incremental Learning Models	High	High	Normal/Low	High	High	Increase in a semantic context	Increase in a semantic context	Increase in a semantic context	No	No	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
	Low	Low	High	Low	Low	No influence of semantic context	No influence of semantic context	No influence of semantic context	Omissions are stable across time intervals	No	No Interference across quartiles	Normal	Normal	Normal	Normal	Normal	No	No	No effect across quartiles
Executive Control Models	High	Normal	Low	High	High	No influence of semantic context	Increase in a semantic context	Increase in a semantic context	No	Yes	High	High	High	Normal/High	Normal/High	High	High	High	High

Note. *High= significant positive difference as compared either to aphasic patients in the other group (high or low interference in terms of naming latencies) or to healthy controls; Low= significant negative difference as compared either to aphasic patients in the other group (high or low interference in terms of naming latencies) or to healthy controls; Normal: No significant difference with the other aphasic group of with healthy controls. For executive control models have only been posited predictions about their disruption. In our knowledge these models predict only a exceeding interference across several tasks.*

Experiment 1

Here, we extensively tested distinct patterns of lexical retrieval deficits (see Table 5) by comparing the performance of aphasic patients with those of healthy individuals in a continuous picture naming task.

Method

Participants

20 patients with aphasia (PwA: 14 males; mean age 58, SD 13; mean education 13, SD 3) and 15 healthy controls (HCs: 10 males; mean age 52, SD 12; mean education 13, SD 2), with no history of neurological disease or psychiatric impairment, were recruited for the present study. All gave their informed consent to take part in the study, which was approved by the local Ethics Committee. Patients were recruited at the IRCCS Fondazione Santa Lucia in Rome and were being treated for language impairment, hemiparesis or hemiplegia following cerebrovascular accident (CVA). Inclusion criteria were the following: language impairments after a single CVA involving the left hemisphere, a relatively preserved ability to name pictures and a sufficient ability to understand instructions. Exclusion criteria were: two or more CVAs, neoplastic or traumatic aetiology, presence of cognitive deterioration. Patients' personal and clinical data are provided in Table 6. All healthy controls claimed to have normal or corrected to normal vision, were right-handed, and had no language impairment.

Table 6. *Personal and clinical data of patients with aphasia.*

Patient	Gender	Age	Education	Time from Stroke (months)	Lesion Site
A.R.S.	M	47	13	2	Fr; T; P
B.C.	M	51	8	4	T; I; In
B.P.	M	71	18	6	T; O
C.G.	M	60	13	12	Fr; I; bg; In
C.M.	F	54	13	24	Fr; I; In
C.R.	M	49	8	2	Fr; T; I
Ca.S.	M	57	13	9	th; ic; In
Ce.M.	F	46	13	5	P
Co.S.	M	65	13	7	T; P
D.L.	M	50	13	3	T
G.G.	F	68	18	2	Fr
G.M.	F	38	13	2	Fr
Ol.A.	M	57	13	4	Fr; I
P.S.	M	78	8	5	Fr; I
R.P.	F	62	13	4	P; O
R.R.	M	80	13	3	Fr
S.B.K.	M	23	13	4	ic; In; cr
S.C.	F	66	13	3	bg; T; I
S.M.	M	53	18	6	cn; ic
S.P.	M	75	5	7	P; O

Note. m= male; f = female; th = thalamus; ic = internal capsula; In = lenticular nucleus; Fr = frontal lobe; I = insula; cr = corona radiata; T = temporal lobe; O = occipital lobe; bg= basal ganglia; cn = caudate nucleus; P = parietal lobe.

Neuropsychological Testing

All brain-damaged patients were submitted to a neuropsychological battery (see Table 7) that assessed abstract or verbal reasoning (Raven, 1938; Basso et al. 1987;), language (Capasso & Miceli, 2001; or Ciurli et al. 1996; or Miceli et al. 1994), semantic knowledge (Novelli et al. 1986; Gamboz et al. 2009). Neuropsychological assessment was carried out by one of the author (I.B.), an expert neuropsychologist. Different tests were used across participants to assess noun naming and other capacities depending on: a) the degree of their language impairment; b) their education. Indeed, the Neuropsychological Assessment for Aphasia (E.N.P.A.; Capasso & Miceli, 2001), well suits with those patients with severe language deficits and low education. On the other hand, the "Esame del Linguaggio" (Ciurli, Marangolo & Basso, 1996) and the Battery for the Analysis of Aphasic Disorders (B.A.D.A.; Miceli et al. 1994), well suits for those patients with language deficits from minor to moderate and high education. Particularly, B.A.D.A. was used as a fine-grained analysis of patients' phonological, lexical-semantic and syntactic capacities.
Neuropsychological testing highlighted that no participant had mental deterioration.

Table 7. *Patients' performance in neuropsychological tests.*

Patient	Group	Nouns Naming	Verbs Naming	Word Repetition	Token Test	Verbal Fluency (Phonemic)	Verbal Fluency (Semantic)	Pyramids and Palm TreesTest	Denomination Under Description Test	Spontaneous Speech Fluency	Errors in Naming Test (Nouns and Verbs Naming)
A.R.S.	Group 1	7**(d)	7**(n)	10**(n)	34/36(n)	4(d)	8(d)	49,54(n)	36(n)	Fluent	Semantic Paraphasia; Anomia;
B.P.	Group 1	3/30*(n)	2/28*(n)	0/45*(n)	35/36(n)	13(d)	9(d)	48,85(n)	36,50(n)	Fluent	Circumlocution; Semantic Paraphasia; Anomia
C.R.	Group 1	4**(d)	3,9**(d)	9,8**(n)	30/36(d)	2(d)	9(d)	48,50(n)	36(n)	Fluent	Semantic Paraphasia; Anomia
Ce.M	Group 1	3/30*(n)	9/28*(d)	6/45*(d)	//	5(d)	8(d)	//	//	Non-fluent	Semantic Paraphasia
Ol.A.	Group 1	1/30*(n)	4/28*(d)	0/45*(n)	32/36(n)	7(d)	10(d)	49(n)	30(d)	Non-fluent	Semantic Paraphasia; Anomia
R.R.	Group 1	18/30*(d)	13/28*(d)	3/45*(d)	13/36(d)	2(d)	2(d)	43,14(n)	29,5(d)	Non-fluent	Semantic Paraphasia
S.B.K.	Group 1	14/30*(d)	16/28*(d)	10**(d)	16/36(d)	2(d)	7(d)	45,06 (n)	22(d)	Non-fluent	Semantic Paraphasia
S.M.	Group 1	0/30*(n)	4/28*(d)	0/45*(n)	31/36(n)	2(d)	9(d)	47,60(n)	25(d)	Fluent	Semantic Paraphasia
B.C.	Group 2	6**(d)	8,9**(n)	9,8**(n)	20/36(d)	1(d)	5(d)	49,80(n)	27(d)	Fluent	Anomia
C.G.	Group 2	7**(d)	6**(d)	6**(d)	34/36(n)	2(d)	1(d)	42,04(n)	26(d)	Non-fluent	Anomia
C.M.	Group 2	2/30*(n)	2/28*(n)	0/45*(n)	35/36(n)	2(d)	6(d)	48,60(n)	36(n)	Non-fluent	Semantic Paraphasia; Anomia;
Ca.S.	Group 2	5/30*(d)	6/28*(d)	0/45*(n)	34/36(n)	8(d)	10(d)	49(n)	35(n)	Non-fluent	Semantic Paraphasia
Co.S.	Group 2	6/30*(d)	3/28*(d)	0/45*(n)	30/36(d)	7(d)	9(d)	47,20(n)	33(d)	Fluent	Circumlocution; Semantic Paraphasia; Anomia
D.L.	Group 2	4**(d)	5**(d)	6,8**(d)	34/36(n)	1(d)	10(d)	//	//	Fluent	Circumlocution; Semantic Paraphasia
G.G.	Group 2	6**(d)	5**(d)	10**(n)	//	1(d)	4(d)	22,58(d)	25(d)	Non-fluent	Semantic Paraphasia; Anomia
G.M.	Group 2	3**(d)	1,5**(d)	8,8(n)	35/36(n)	3(d)	8(d)	46,69(n)	28(d)	Fluent	Neologism; Semantic Paraphasia; Anomia
P.S.	Group 2	22/40***(d)	6/20***(d)	30/40***(d)	//	0(d)	2(d)	38,25(d)	27,50(d)	Fluent	Semantic Paraphasia; Anomia
R.P.	Group 2	10**(n)	10**(n)	10** (n)	22/36(d)	7(d)	9(d)	47,51(n)	36(n)	Fluent	Anomia
S.C.	Group 2	5/30*(d)	6/28*(d)	10(n)	31/36(n)	7(d)	5(d)	48,51(n)	32(d)	Fluent	Circumlocution; Semantic Paraphasia; Anomia
S.P.	Group 2	9**(n)	5**(d)	6,2**(d)	12/36(d)	3(d)	6(d)	46,69(n)	33,25(d)	Fluent	Semantic Paraphasia

*Note. * = Battery for the Analysis of Aphasic Disorders, B.A.D.A. (Miceli, Laudanna, Burani, & Capasso, 1994). In this battery errors are counted for each task; ** = Neuropsychological Assessment for Aphasia, E.N.P.A. (Capasso & Miceli, 2001). In this battery corrected answers are counted for each task; *** = Esame del Linguaggio (Ciurli, Marangolo, & Basso, 1996). In this battery corrected answers are counted for each task; d = deficit performance; n = normal performance; // = test not performed*

Apparatus

Participants seated in a noise-isolated room. Stimuli were displayed on a laptop computer screen (screen size: 15''). Latencies were registered using a voice-key (PST Serial

Response Box) and a microphone. Stimulus presentation and response times were controlled by means of E-Prime 2 software. A practice session was provided in order to familiarize with the task. During this session, participants were instructed to avoid self-corrections, making unnecessary noises (e.g., coughing, sneezing) to prevent false triggering of the voice key. Furthermore, participants were strongly recommended to: a) respond only when they were certain it was the correct response; b) "avoid making sounds such as "erm", "err", "hmm", and so on; c) open their mouth slightly in preparation for each picture presentation.

Experimental Task: Continuous Picture Naming

165 line-drawing pictures obtained from a variety of sources made up the stimuli. 120 were experimental stimuli and 45 "fillers" (Appendix 16). Experimental pictures were drawn from 24 semantic categories, with 5 exemplars for each category. Presentation of the stimuli followed Howard et al. (2006): the first and last five items were filler items; each category was presented in a sequence that separated category members by 2, 4, 6, or 8 intervening items (lag), which were either fillers or pictures from other categories; each category was inserted into one of the 24 possible lag order sequences and category members were assigned to an ordinal position (i.e., 1 to 5) in the lag sequence. In the literature, this structure is well known to induce a linear increase of both reaction times (Howard et al. 2006) and errors (Navarrete et al. 2010) as a function of ordinal position (cumulative semantic interference). Importantly, interference is not affected by lag, i.e., the number of intervening items. In other words, during this task, the previous naming of a picture (e.g. dog) will make the naming of a successive related picture (e.g. cat) slower and more prone to errors. This structure was repeated twice in order to create two experimental lists with the same stimuli. In each list, the order of categories as well as their exemplars was not the same. The two lists were presented in a blocked fashion in order to study priming mechanisms (repetition priming; see Mulatti et al. 2014 for a similar procedure). A small self-paced break was provided between the two lists. To make sure that positional effects were not confounded with lexical variables, in both lists items were matched across each ordinal position according to frequency and word length (CoLFIS database: Goslin et al. 2014).

Participants were instructed to name the pictures as fast and as accurately as possible. Participants were also asked to avoid making unnecessary noise (e.g., coughing, sneezing) to prevent false triggering of the voice key. The task was self-paced. Each naming trial started with a question ("ready?") that disappeared as soon as participant was ready to start. Then a fixation cross was showed for 1000ms followed by a blank screen for 250ms.

Stimuli were then presented and remained on the screen until the participant made a verbal response. The naming trial finished with a blank screen presented for 500ms and the next trial started. Naming responses were scored off-line using a tape recorder. Near-synonyms (e.g., “mule” instead of “donkey”) were scored as correct. Responses were scored as errors if the name was incorrect or no response was given. Furthermore, errors were classified as: “omission” (no name was provided for a picture), “superordinate” (e.g. “insect” instead of “ant”), “coordinate” (e.g. “cat” instead of “dog”), “not related” (e.g. “chair” instead of “hammer”) and “within-set errors” (the same name as produced in a preceding trial).

Results

Overall Group

Firstly, we carried out an analysis on the reaction times to investigate a general difference in terms of semantic interference between PwA and HCs in both lists. For these analyses omitted or incorrect responses were excluded (HCs mean 3%; PwA mean 19%). Latencies below 250ms (false trigger) and above 3 standard deviation (outliers) of the participants' overall mean were also removed (HCs mean 4%; PwA mean 12%). In the literature, cumulative semantic interference has been conceived as an increase of RTs as a function of ordinal positions. So, the remaining data were submitted to a first 2x2x5 ANOVA with Group (PwA, HCs) treated as a between factor and List (list 1, list 2) and Ordinal position (1 to 5) as within factors. Figure 15 and Table 8 show the results. The analysis highlights a significant main effect of Group ($F_{1,25}$= 21.10, p < .01, n^2_p= .45), with higher reaction times in PwA (2501ms) than in HCs (982ms); a repetition priming effect, that is a significant main effect of List ($F_{1,25}$= 28.22, p < .001, n^2_p= .53); a significant Group by List interaction ($F_{1,25}$= 4.67, p = .04, n^2_p= .15), with PwA showing a higher priming effect as compared with HCs; and a main effect of Ordinal position ($F_{4,100}$= 3.32, p = .01, n^2_p= .11), i.e., the expected effect of cumulative semantic interference. However, the List by Ordinal position ($F_{4,100}$= 1.32, p = .26, n^2_p= .05), the Group by Ordinal position ($F_{4,100}$= 1.41, p = .23, n^2_p= .05), and the Group by List by Ordinal position ($F_{4,100}$= 1.29, p = .27, n^2_p= .04) interactions were not significant.

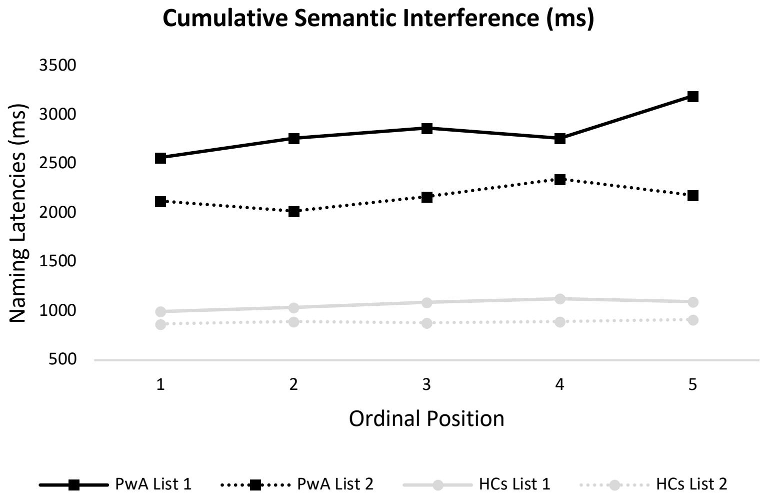

Figure 15. *Cumulative semantic interference (ms) in PwA and HCs in both lists.*

Table 8. *Reaction times in PwA and HCs as a function of ordinal positions for both lists. Standard error is reported in bracket.*

		Ordinal Positions					Mean
		1	2	3	4	5	
PwA	List 1	2569 (234)	2764 (339)	2867 (265)	2763 (294)	3197 (364)	2832 (299)
	List 2	2123 (191)	2022 (202)	2170 (273)	2350 (372)	2180 (266)	2169 (261)
Mean		2346 (212)	2393 (270)	2519 (269)	2556 (333)	2689 (315)	2501 (280)
HCs	List 1	997 (60)	1042 (63)	1094 (68)	1128 (84)	1100 (68)	1072 (69)
	List 2	872 (37)	893 (31)	882 (29)	894 (32)	916 (33)	892 (32)
Mean		935 (48)	968 (47)	988 (49)	1011 (58)	1008 (51)	982 (51)

Since the fact that PwA had higher response times than HCs might undermine further analyses, we recomputed response latencies for each participant as the ratio of RTs for the 2nd, 3rd, 4th and 5th ordinal positions relative to the RTs of the 1st position (baseline) (hereafter referred to as Relative Reaction Times or RRTs). Doing so, RTs for each ordinal position were computed as a variation, in terms of percentage, from the baseline. Subsequently, RRTs were resubmitted to a 2x2x5 mixed ANOVA (see Figure 16, Table 9). Consistently with previous ANOVA, RRTs' results showed a repetition priming effect with a main effect of List ($F_{1,25}$= 5.27, p = .03, n^2_p= .17), but no Group by List interaction ($F_{1,25}$= .5, p = .48, n^2_p= .02). Results also replicated the main effect of Ordinal position ($F_{4,100}$= 7.76, p < .01, n^2_p= .23) and the size of the interference did not differ between groups (Group by Ordinal position: $F_{4,100}$= 1.15, p = .33, n^2_p= .04) and lists (List by Ordinal position: $F_{4,100}$= 2.02 p = .1, n^2_p= .07). Moreover, there was no Group by List by Ordinal position interaction ($F_{4,100}$ = .09, p = .76, n^2_p= .004). Despite the similar results, RRTs did not report a significant difference between groups ($F_{1,25}$= .09, p = .76, n^2_p= .004), i.e., the PwA group and HCs did not differ in terms of RRTs.

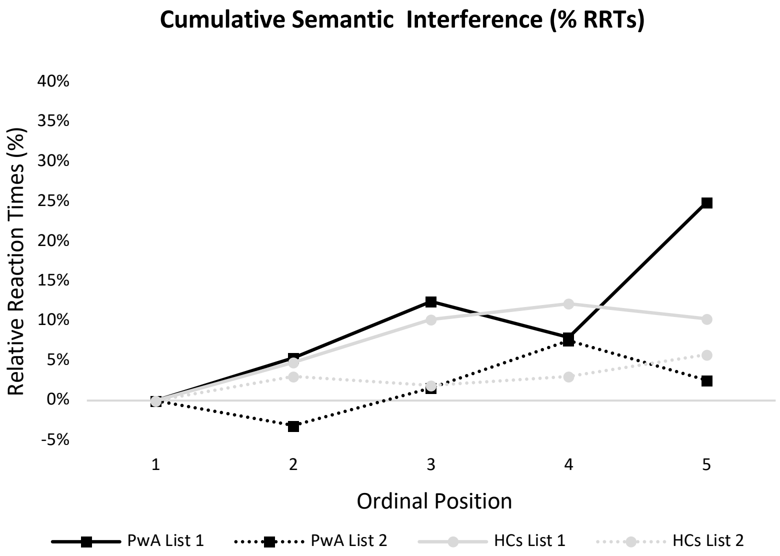

Figure 16. *Cumulative semantic interference (%RRTs) in PwA and HCs in both lists.*

Table 9. *Relative reaction times in PwA and HCs as a function of ordinal positions for both lists. Standard error is reported in bracket*

		Ordinal Position				
		1	2	3	4	5
PwA	List 1	0% (0)	5% (5)	12% (4)	8% (5)	25% (8)
	List 2	0% (0)	-3% (5)	2% (6)	8% (7)	3% (5)
HCs	List 1	0% (0)	4% (3)	10% (4)	12% (3)	10% (2)
	List 2	0% (0)	3% (2)	2% (2)	3% (2)	6% (2)

To further explore differences between PwA and HCs we estimated a cumulative semantic interference index for RRTs for each of the two lists. This index was computed by averaging RRTs in the first two (hereafter "1+2") and the last two positions (hereafter "4+5") and by calculating the difference between them ((4+5)-(1+2)). Then, this index was submitted to a 2x2 ANOVA with Group as a between factor and List as a within factor. Despite the semantic interference index seemed to decrease in list 2 as compared to list 1 in both groups (Figure 16), this trend was not significant ($F_{1,25}$= 3.48, p = .07, n^2_p= .12). Furthermore, the analysis failed to report a Group by List interaction ($F_{1,25}$= .30, p = .58, n^2_p= .01; Figure 17) and a main effect of Group ($F_{1,25}$= 1.67, p = .20, n^2_p= .06).

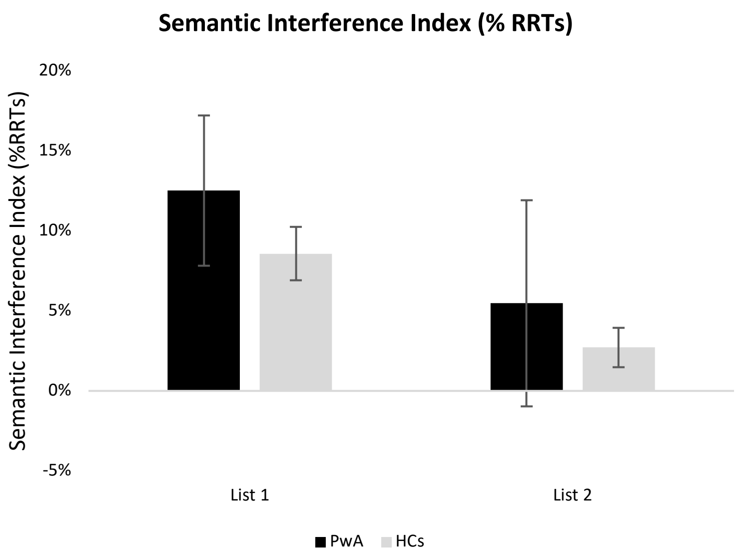

Figure 17. *Cumulative semantic interference index for PwA and HCs in both experimental lists. Bars depicted the standard error.*

Crawford's Analysis

Variability in naming latencies has been widely documented in aphasia (Obler et al. 1995; Nespoulous 2000), along with the unevenness of symptomatology (Krishnan et al. 2012). So, studying aphasic patients as a homogeneous group may be misleading. Some works addressed this problem by aggregating patients in subgroups relying on symptomatology (Broca vs Non Broca; e.g. Schnur et al. 2006) or lesion site (e.g. anterior vs posterior; e.g. Jefferies et al. 2007). On the other hand, some authors (Olson and Romani 2011) suggested that the aggregation should depend on the theoretical question as well as the characteristic of the data. Here, we posited that the extent to which patients are susceptible to semantic context, especially in terms of reaction times, may play a crucial role in disentangle the locus where lexical retrieval deficits origins (see Biegler et al. 2008 for a similar idea).

Specifically, as we discussed earlier, if semantic interference reflects an exceeding activation (activation models: Roelofs 1992; Levelt et al. 1999), patients with higher semantic interference should experience a situation of "too much activation" of both target representations and its semantic neighbours (Vitkovitch and Humphreys 1991; Damian et al. 2001; Belke et al. 2005). Accordingly, in these patients a coherent pattern of results should emerge in those tasks eliciting semantic interference during lexical retrieval, i.e., an increase in naming latencies and more coordinate and perseveration errors when naming occurs in a semantic context. Furthermore, since, in the literature, the activation mechanisms have been conceived to be temporary (Collins and Loftus 1975; Belke et al. 2005), semantic and perseveration errors should decrease as a function of time. Additionally, this state of "too much activation" may also be modulated by priming mechanisms, coherently with Howard et al. (2006). On the other hand, the lack of semantic interference might be attributed to an "under-activation of semantic/lexical nodes, which would result in higher naming latencies, omissions and a reduced repetition priming (Hillis et al. 1990; Wilshire and McCarthy 2002). A "too much activation" state may also be the consequence of damage to the external control mechanisms (Thompson-Schill et al. 1999; Schnur et al. 2006; Schnur et al. 2009). In such a case, patients should perform quite consistently in different tasks inducing interference (e.g. semantic probe and Stroop task). Alternatively, semantic interference may rely on inhibitory mechanisms (inhibition models: Brown 1981; Harley and MacAndrew 1992; Harley 1993; Chen and Mirman 2012). Consistently with this approach, one may assume that patients with higher interference experience a pathological refractory state (McNeil et al. 1994; Forde and Humphreys 1997; Warrington and Crutch 2004; Forde and Humphreys 2013). In other words, the retrieval of a target would induce a significant inhibition of its competitors, making their successive retrieval slower and more prone to omissions. Furthermore, similarly to activation mechanisms, refractoriness seems to be temporary (e.g. see Mirman and Britt 2014), so omission errors should decrease as a function of time. Conversely, the absence of semantic interference could be the results of a degradation of inhibitory connections resulting in a pattern of results similar to the "too much activation" state: more coordinate errors and perseverations when a target is provided in a semantic context.

Thus, we merged the data of list 1 and list 2 and computed the cumulative semantic interference index in terms of RRTs (see above the computation of this index). This index was then submitted to a Crawford's analysis (Crawford and Howell 1998; Crawford and Garthwaite 2002) to determine whether each patient's scores were significantly higher than those of the healthy control participants. This approach "…uses a formula given by Sokal and Rohlf (reference) that treats the statistics of the normative or control sample as statistics rather than as population parameters and uses the t-distribution (with N–1 degrees of freedom (d.f.)), rather than the standard normal distribution, to evaluate the abnormality of the individual's scores. Essentially, this method is a modified independent samples t-test in which the individual is treated as a sample of M=1, and therefore does not contribute to the estimate of the within group variance" (p.1197; Crawford and Garthwaite 2002). Crawford's analysis is also a suitable analysis when the normative sample is small (i.e., fewer than 50 individuals; see Palermo et al. 2012).

Crawford's analysis showed that eight aphasic patients had higher cumulative semantic interference than HCs (Group 1) and the remaining twelve patients showed lower or similar interference than HCs (Group 2). Table 10 summarizes the results.

Table 10. *Results of Crawford Analysis. Patient's semantic interference score and the statistics for each comparison are provided.*

Participant	Group	Cumulative Semantic Interference Index (RRTs)	Single-case analysis on semantic index (Crawford & Howell, 1998)	TR Baseline (Position 1)	Errors Baseline (Position 1)
AS	Group 1	23%	t(14)= 4.11; p= .001	1709	8%
BP	Group 1	33%	t(14)= 6.53; p < .001	4200	23%
CR	Group 1	20%	t(14)= 3.38; p= .004	1469	15%
CeM	Group 1	23%	t(14)= 4.11; p= .001	3388	21%
OL	Group 1	19%	t(14)= 3.14; p= .007	1494	6%
RR	Group 1	22%	t(14)= 3.87; p= .001	4435	25%
SBK	Group 1	19%	t(14)= 3.14; p= .007	2943	25%
SM	Group 1	25%	t(14)= 4.59; p < .001	2396	13%
BC	Group 2	5%	t(14)= 0.24; p= .81	2405	54%
CG	Group 2	-7%	t(14)= -3.14; p= .007	2938	21%
CM	Group 2	5%	t(14)= 0.24; p= .81	2605	21%
CaS	Group 2	-12%	t(14)= -4.35; p= .001	1781	8%
CoS	Group 2	14%	t(14)= 1.93; p= .07	1809	31%
DL	Group 2	-13%	t(14)= -4.59; p< .001	2907	8%
GG	Group 2	-3%	t(14)= -2.17; p= .04	2737	23%
GM	Group 2	9%	t(14)= 0.72; p= .48	1079	13%
PS	Group 2	5%	t(14)= -0.24; p= .81	876	46%
RP	Group 2	2%	t(14)= -0.96; p= .34	2116	6%
SC	Group 2	-17%	t(14)= -5.56; p < .001	3075	4%
SP	Group 2	-11%	t(14)= -4.11; p= .001	3874	25%
Healthy Controls	Controls	Mean= 6%; SD= 4%	__________________		

Although the grouping of patients depending on their behavioural performance was plausible, one would think that patients within groups shared more similarities than patients across groups. In order to test this hypothesis, we compared these two groups in terms of gender, age, education, time from the stroke and their performances in the neuropsychological tests.

Results showed that none of the variables took into account differed between the two groups as reported in table 11.

Table 11. *Results of comparisons between PwA groups.*

	Group 1 (N=8)	**Group 2 (N=12)**	**Group Differences**		
Characteristics	Frequency/Mean (SD)	Frequency/Mean (SD)	χ^2(df)/t(df)	P-Value	Effect Size
Gender (Male; M/Female; F)	M: 7; F: 1	M: 7; F: 5	χ^2 (1) 1.94	.16	Cramer's v 0.31
Age (in years)	53 (17)	60 (11)	t (18) -1.12	.28	Cohen's d -0.48
Education (in years)	14 (3)	12 (3)	t (18) 1.13	.27	Cohen's d 0.66
Onset (in months)	4 (2)	7 (6)	t (18) -1.25	.23	Cohen's d -0.67
Fluency in Spontaneous Speech (Fluent; F/Non-Fluent; NF)	F: 4; NF: 4	F: 8; NF: 4	χ^2 (1) 0.55	.46	Cramer's v 0.16
Token Test	27 (9)	29 (8)	t (16) -0.34	.70	Cohen's d -0.23
Verbal Fluency (Phonological)	5 (4)	4 (3)	t (18) 0.75	.47	Cohen's d 0.28
Verbal Fluency (Semantic)	7 (3)	5 (3)	t (18) 1.32	.20	Cohen's d 0.66
Pyramids and Palm Trees Test	47 (2)	44 (8)	t (16) 1	.33	Cohen's d 0.51
Denomination Under Description Test	31 (6)	31 (4)	t (16) -0.35	.97	Cohen's d -0.01
Nouns Naming (Deficit; D/Non Deficit; ND)	D: 4; ND: 4	D: 9; ND 3	χ^2 (1) 1.31	.25	Cramer's v 0.25
Verbs Naming (Deficit; D/Non Deficit; ND)	D: 6; ND: 2	D: 9; ND 3	χ^2 (1) 0.37	.80	Cramer's v 0.43
Word Repetition (Deficit; D/Non Deficit; ND)	D: 3; ND: 5	D: 4; ND 8	χ^2 (1) 0.37	.85	Cramer's v 0.43
Number of Patients who produced Anomia; A and/or Semantic Paraphasia; SP	A: 4 SP: 8	A: 6 SP: 7	χ^2 (1) 0.48	0,51	Cramer's v 0.13

Reaction times. In order to explore whether the two subgroups showed different patterns of cumulative semantic interference, RRTs were submitted to a 3x5 mixed ANOVA, with Group (Group 1; Group 2; HCs) as a between factor and Ordinal position (from 1 to 5) as a within factor. Results highlighted a significant Group by Ordinal position interaction ($F_{8,128}$=7.86, p < .001, n^2_p= .32). Precisely, RRTs showed a cumulative increase for Group 1 ($F_{1,7}$=70.92, p < .001, n^2_p= .91) and HCs ($F_{1,14}$=24.05, p < .001, n^2_p= .63), but not for Group 2 ($F_{1,11}$= .001, p= .97, n^2_p= .001; Figure 18 and Table 12).

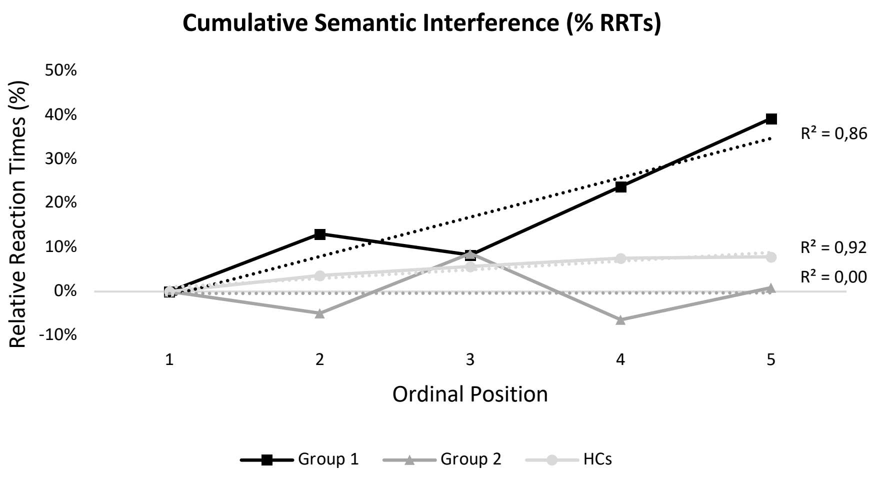

Figure 18. *Cumulative semantic interference in PwA subgroups and HCs. Dotted line and R^2 report the linear trend of data.*

Table 12. *RRTs and untreated RTs in PwA subgroups and HCs as a function of ordinal positions. Standard error is reported in bracket.*

		Ordinal Positions				
		1	2	3	4	5
RRTs	Group 1	0%(0)	13%(6)	8%(7)	24%(6)	39%(7)
	Group 2	0%(0)	-5%(4)	9%(4)	-6%(4)	1%(7)
	HCs	0%(0)	4%(1)	6%(2)	8%(1)	8%(2)
Untreated RTs	Group 1	2754(419)	3198(557)	3053(557)	3486(634)	3928(672)
	Group 2	2350(249)	2225(280)	2535(278)	2156(237)	2310(252)
	HCs	935(45)	968(46)	986(47)	1009(56)	1009(51)

Groups were also compared in terms of repetition priming. A repetition priming index was computed by subtracting the RRTs in the first list from those in the second list. This index was then submitted to a one-way ANOVA. Results showed a main difference between groups ($F_{1,25}$= 4.13, p= .02, n^2_p= .25). A Bonferroni corrected comparison highlighted a greater repetition priming in Group 2 as compared to HCs (p= .02), but no difference was found between Group 2 and Group 1 (p > .05; Figure 19).

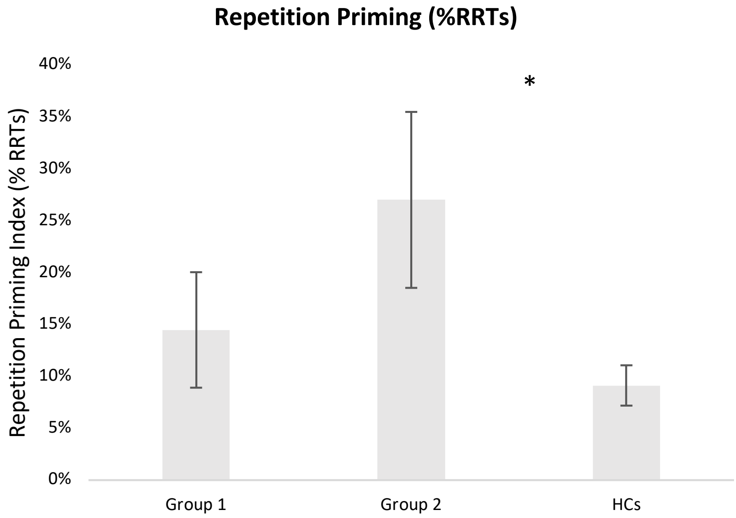

Figure 19. *Repetition priming index for PwA subgroups and HCs. Bars depict the standard error and the asterisks the significant comparison.*

Errors. A 3x5 mixed ANOVA was carried out with Group as a between factor and Ordinal position as a within factor. Errors confirmed a Group by Ordinal position interaction ($F_{8,128}$=, p= .01, n^2_p= .13), but with a different trend: a linear increase of errors was showed in HCs ($F_{1,14}$= 7.85, p= .01, n^2_p= .35) and Group 2 ($F_{1,11}$= 22.56, p= .001, n^2_p= .67), but no trend in Group 1 ($F_{1,7}$= 3.34, p= .11, n^2_p= .32; Figure 20).

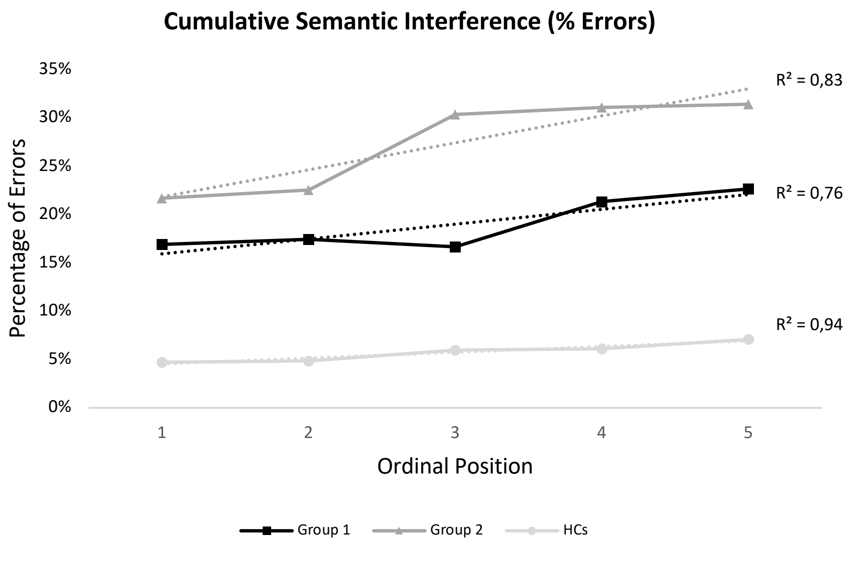

Figure 20. *Cumulative semantic interference in PwA subgroups and HCs. The dotted line and R^2 reports the linear trend of data.*

Summarizing, these analyses highlighted a high semantic interference in Group 1 as compared in Group 2 in terms of RRTs (Figure 18). This trend was reversed in terms of errors (Figure 20). These results could be attributed to a more general speed-accuracy trade off: all patients would be equally susceptible to interference, but they would differ for their capacity to adjust response either maintaining the accuracy, but increasing naming latencies (Group 1) or, vice versa, providing a wrong impulsive response (Group 2). In order to exclude this hypothesis, we compare PwA's performances in terms of both raw reaction times and errors at baseline (first ordinal position, see Table 10). Both the reaction times and the errors of the first ordinal position were submitted to two separate one-way ANOVAs. If the PwA subgroups differed in terms of a speed accuracy trade off, we would expect: a) higher reaction times in the first ordinal position for group 1; b) higher percentage of errors for group 2. Both ANOVAs failed to report a significant result for raw reaction times (Group 1 mean 2754ms SD 1184; Group 2 mean 2350ms SD 862; $F_{1,18}$= .78, p= .38, n^2_p= .04) and errors (Group 1 mean 17% SD 8; Group 2 mean 22% SD 16; $F_{1,18}$= .59, p= .44, n^2_p= .03).

Error Types. Previously we posited that our grouping would shed light about the mechanisms underlying errors during word selection in aphasics. Precisely, we supported the idea that our aphasic subgroups might exhibit different patterns of behaviour in terms of type of errors. In order to investigate these differences, superordinate, unrelated, coordinate, omission errors and within-set errors were submitted to separate one-way ANOVAs. Comparisons were performed across all three groups (Group 1, Group 2 and HCs) but for omission errors, only PwA were compared because HCs did not make this kind of errors. Results showed that the two PwA subgroups did not differ in terms of superordinate errors ($F_{3,32}$= 2.44, p= .1, n^2_p= .13), unrelated errors ($F_{3,32}$= 1.97, p= .15, n^2_p= .11) and omissions ($F_{1,18}$= .50, p= .48, n^2_p= .02), but differed in terms of coordinate errors ($F_{2,32}$= 12.25, p < .001, n^2_p= .43) and within-set errors ($F_{3,32}$= 8.004, p= .002, n^2_p= .33). Bonferroni corrected post-hoc comparisons for coordinate errors highlighted that Group 2 were more likely to produce this type of error as compared with Group 1 (p= .02) and HCs (p < .001). Furthermore, Group 1 made more coordinate errors than HCs (p= .04). Similarly, Bonferroni corrected post-hoc comparisons carried out on within set errors showed that this type of error was more frequent in Group 2 than in Group 1 (p= .02) and HCs (p= .002), however there was no difference between Group 1 and HCs (p > .05; Figure 21).

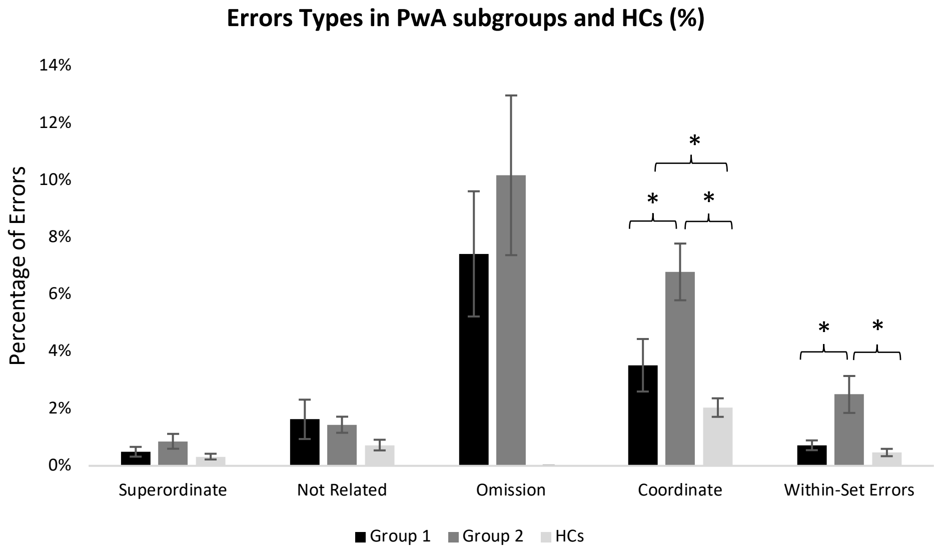

Figure 21. *The mean of percentage for each type of error. Bars report the standard error. The asterisks highlight the significant comparisons.*

So far, Group 1 showed a greater cumulative semantic interference just for RRTs. Conversely, Group 2 exhibited no interference in terms of RRTs, but made more coordinate and within-set errors as compared with the patients in Group 1 and HCs. Thus, results did not match the predictions suggested by activation models: more semantic errors in patients with high interference. By contrast with this view, data were more prone to validate the inhibition models, in which semantic interference, in terms of naming latencies, relies on a lateral inhibition of competitors. As we discussed earlier, the disruption of these inhibitory mechanisms may result in an exceeding activation in the lexical system. Consistently with this approach, Group 1 would show a prolonged inhibition, which leads to a pathological refractory state (see Forde and Humphreys 1997; McCarthy and Kartsounis 2000; Forde and Humphreys 2013). This is, the retrieval of a target word would induce a significant decrease of activation in the semantically related nodes, making their successive retrieval slower. On the other hand, results in Group 2 might be interpreted as a degradation of inhibitory mechanisms, which would induce a disproportionate activation of semantically related competitors ("too much activation"; see for example Mirman and Britt 2014). This "too much activation" would lead to a higher frequency of semantic substitutions and perseverative (within-set errors) responses during a naming task.

Cumulative Semantic Interference per Error Type. Here, we take a deepest look to the extent to which patients' performances could be ascribable to either a refractory state or to a damage of inhibitory mechanisms. Consistently with this goal, we analysed the trend of errors (omissions, coordinate, within-set errors, superordinate and unrelated) across ordinal positions. Specifically, two different predictions for Group 1 and Group 2 were advanced consistently with inhibition models: a) in Group 1 the inhibition of a non-target stimulus plus the inability of the system to boost its activation makes its successive retrieval slower or more prone to omission. Thus, an increase of omission across ordinal positions was expected in this subgroup; b) conversely, in Group 2 an impairment of inhibition might result in an exceeding activation of the target and its semantically related nodes. So, an increase of coordinate errors across ordinal positions should be predicted. Furthermore, in Group 2 the lack of inhibition and a sparing of priming mechanisms (as reported in the previous analysis) would lead to an increase of within-set errors. In other words, the naming of a category exemplar (e.g. dog) may result either in a residual activation (e.g. Belke et al. 2005) or in the strengthening of its semantic-to-lexical connections (e.g. Howard et al. 2006; Schnur et al. 2006; Hsiao et al. 2009; Oppenheim et al. 2010; Schnur 2014), making that word a primary candidate when the same category is activated by a related item (e.g. cat). This phenomenon should be amplified by the loss of inhibitory connections, this is a new target lexical representation is unable to weaken the connections between the semantic category and the previous retrieved word (Vitkovitch and Humphreys 1991; Vitkovitch 1996; Vitkovitch and Cooper 2012).

The above-mentioned predictions were investigated by means of a 3x5x5 mixed ANOVA with Group as a between factor and Error type (omission, coordinate, within set errors, superordinate and unrelated) and Ordinal position (from 1 to 5) as within factors. Results showed a significant Group by Error type by Ordinal position interaction ($F_{32,512}$= 3.07, $p < .001$, η^2_p= .18). A deepest look at the data showed a linear increase of omissions ($F_{1,7}$= 12.29, p = .01, η^2_p= .63), but not of the other error types, in Group 1 (Figure 22A). Conversely, Group 2 showed a significant linear increase for both coordinate ($F_{1,11}$= 22.03, p = .001, η^2_p= .66) and within-set ($F_{1,11}$= 3.24, p = .01, η^2_p= .43) errors, but not for omissions (Figure 22B). No linear trend was found for any type of error in HCs (Figure 22C).

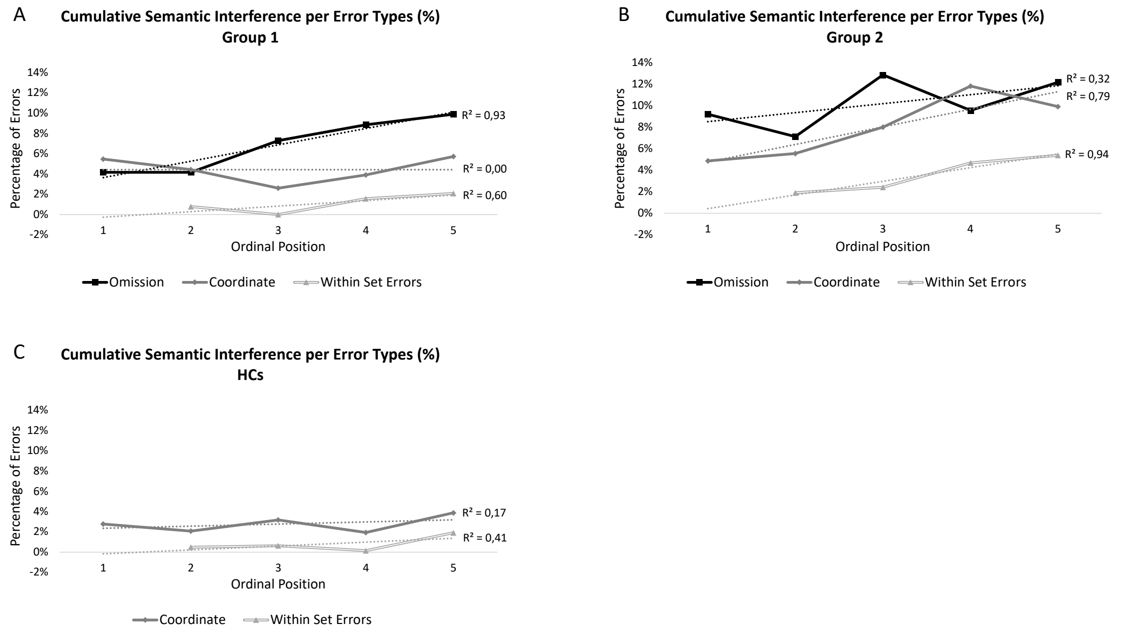

Figure 22. *Increase of each type of error as function of ordinal positions in group 1(A), group 2(B) and HCs(C). Dotted line and R^2 report the linear trend of data. Superordinate and unrelated errors were leaved out to increase the readability of the figure.*

Temporal Characteristics of Within-Set Errors. So far, results reported "production" errors (i.e., coordinate and within-set errors) in Group 2 increased as a function of ordinal positions. These data confirmed an uncontrolled activation of both semantic neighbours and previously activated target words in these patients. A further investigation of within-set errors was carried out by analysing the frequency of these errors at different intervals or lags (Cohen and Dehaene 1998; Hsiao et al. 2009).

Within-set errors occur when a primed object is at a higher level of activation than the target object as a result of the residual activation in the links between semantic and phonological representations (Vitkovitch and Humphreys 1991; Vitkovitch 1996). Campbell and Clark (1989; see also Campbell 1990, 1991) examined perseverative errors in healthy participants during a naming task, in relation to the interval between these errors and original responses. They found that perseverations increased as a function of the intervals and were reduced to the immediately following trials, suggesting a brief inhibitory effect. In this study, we assumed that patients in Group 2 should be more prone to make perseverations in the immediately following trials and reduce their frequency as a function of the interval from the previous target trial. This predicted result should be caused by a damage to an inhibitory control mechanism.

To test this hypothesis, we subdivided the intervals (how many items intervene) between the first retrieval of a target word and the production of its perseverative response into 4 ranges: 1 (from 1 to 6), 2 (from 7 to 12), 3 (from 13 to 24), 4 (higher than 25). Then, a 3x4 ANOVA was carried out with Group as a between factor and Interval range (from 1 to 4) as a within factor. As shown in Figure 23, results reported a significant Group by Lag interaction ($F_{6,90}$= 2.23, p = .04, η^2_p= .12) with a significant decrease of perseveration as a function of intervals only for Group 2 ($F_{1,11}$= 5.89, p = .03, η^2_p= .34).

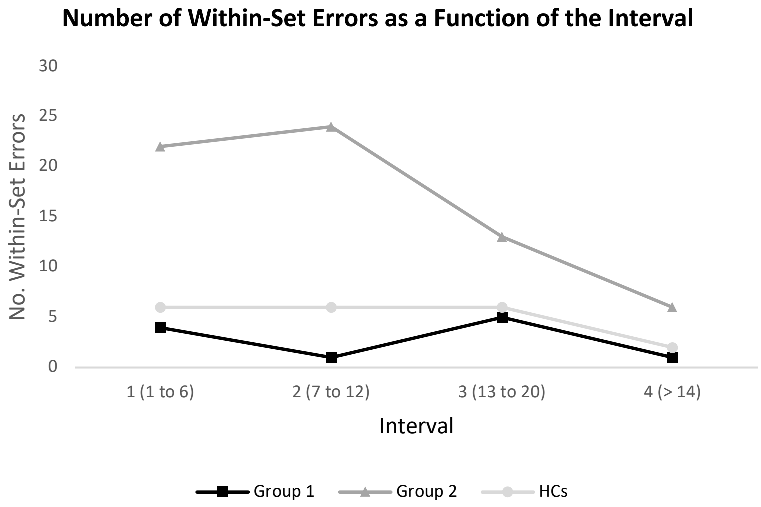

Figure 23. *The number of within-set errors as a function of the distance between the perseverative response and its source.*

Temporal Characteristics of Omissions. So far, the analyses suggested: a) "refractory state" in Group 1, that is a linear increase of omissions through ordinal positions along with cumulative semantic interference in naming latencies; b) a lack of inhibition in Group 2, that is more coordinate and perseverative responses, their linear increase through ordinal positions and more perseverations in the immediately following trials along with the absence of cumulative semantic interference in terms of naming latencies. In the literature, bottom-up inhibitory mechanisms have been conceived to be either temporary (inhibition account: Brown 1991; Harley 1993b; Vitkovitch 1996; Chen and Mirman 2012) or persistent (incremental learning models: Wheeldon and Monsell 1994; Howard et al. 2006; Oppenheim et al. 2010). Here, we compared these two models by testing their predictions. Indeed, consistently with the inhibition models, inhibition/refractoriness is a transient phenomenon, since it dissipates after a time interval. On the other hand, incremental learning models account for persistent changes in semantic to lexical mapping, which induce more long-lasting changes (e.g. the strengthening of inhibitory connections) between semantic and lexical nodes. In order to investigate these two accounts, we tested whether omission errors made by the two PwA subgroups were time-bound or not. Specifically, we compared the trend of these errors in Group 1 and Group 2 as a function of the number of items interspersed between two exemplars of the same category (lag). If omission errors rely on temporary refractoriness, then these errors should decrease as a function of time in Group 1, otherwise this type of error would rely on more persistent changes of semantic to lexical connections (see Oppenheim et al. 2010). We tested these predictions by means of a 2x4 ANOVA with PwA subgroup as a between factor and Lag (2, 4, 6, 8 items) as a within factor.

Though data showed a general decrease of omissions as a function of lag, with a higher linear decrease in Group 1 than in Group 2, these trends were not statistically significant. Indeed, the ANOVA results showed neither a main effect of Lag ($F_{3,54}$= .46, p = .71, η^2_p= .02), nor a Lag by Group interaction ($F_{3,54}$= .22, p = .88, η^2_p= .01; see Figure 24).

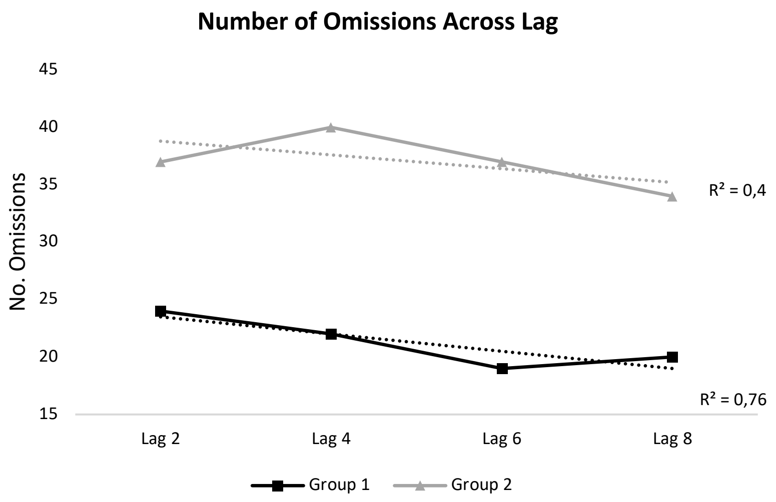

Figure 24. *The number of omissions as a function of the temporal distance between two exemplars of the same semantic category.*

Executive Control Mechanisms in Naming. So far, our analyses suggested a disruption of bottom-up inhibitory mechanisms in Group 2. However, we posited that also a damage of the executive control mechanisms might contribute to the lexical deficits in these aphasic patients (see for example Thompson-Schill et al. 1999; Schnur et al. 2006; Hsiao et al. 2009). These mechanisms lead to the suppression of specific strong competitors to a response induced, for example, by an external distractor (Nigg 2000; Shao et al. 2013; Shao et al. 2015). In Group 1 such external control mechanisms might be relatively spared, but damaged in Group 2, accounting for both the exceeding coordinate and perseveration errors. Here, this hypothesis was investigated by means of delta plot analysis (De Jong et al. 1994; Ridderinkhof et al. 2005; Shao et al. 2013; Shao et al. 2014; Shao et al. 2015). To generate the delta plot, the RTs for each participant and position (1 to 5) were sorted in ascending order and divided into RTs quartiles (25% bins). Then, the semantic interference index was calculated for each quartile. Hence, the delta plot was generated by plotting the quartiles on the horizontal axis and the semantic interference index on the vertical axis. Following De Jong et al. (1994; see also Ridderinkhof, 2002), the slope of the line connecting the delta values for successive quartiles (in the present study the 3rd and 4th quartile) were computed as follows:

$$Slope_{3^{rd},4^{th}} = \frac{\Delta 4^{th} - \Delta 3^{rd}}{\mathrm{mean}3^{rd} - mean4^{th}}$$

Both the delta plot and the slope of the slowest quartiles were conceived as measures of the individual ability to inhibit semantic interference. Consistently with previous studies (Ridderinkhof et al. 2005; Shao et al. 2013; Shao et al. 2015), the absence of an executive control inhibition would result in an increase of interference through all quantiles; conversely, when inhibition occurs, interference decreases for the slowest quantile. For this reason, a 2x4 ANOVA was accomplished with Group as a between factor and the semantic interference in each Quartile (1 to 4) as a within-participant variable. Finally, a further one-way ANOVA was performed with the slope of slowest quartiles as a dependent variable. The ANOVA results did not show a main effect of Quartile ($F_{3,96}$= 1.2, p = .31, partial η^2_p= .03), but a significant Group by Quartile interaction ($F_{6,96}$= 3.65, p= .003, partial η^2_p= .18; see Figure 25). Furthermore, the one-way ANOVA showed a significant effect of Group ($F_{2,32}$= 7.01, p = .003, partial η^2= .30). A Bonferroni corrected post-hoc comparison highlighted a significant difference between Group 1 and Group 2 (p= .003), between Group 1 and HCs (p= .02), but not between Group 2 and HCs (p > .05; see Figure 26).

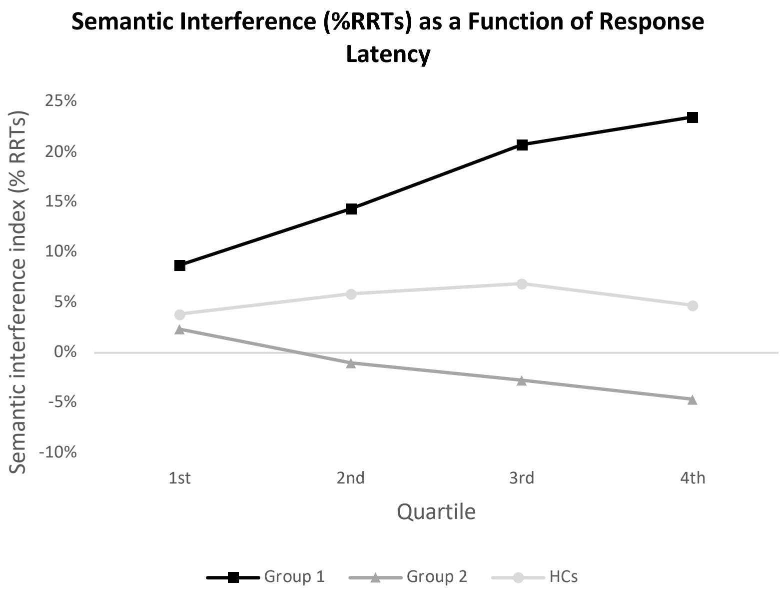

Figure 25. *The trend of semantic interference index as a function of quartiles.*

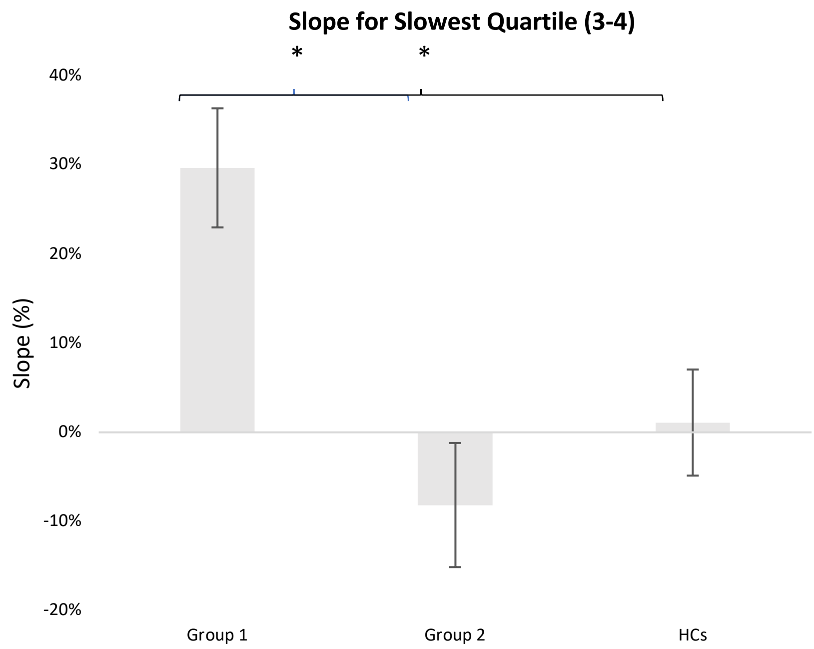

Figure 26. *The slope computed for the slowest quartile in PwA subgroups and HCs. Error bars report the standard errors. The asterisks highlight the significant comparisons.*

Discussion

The experiment 1 was aimed at investigating whether PwA showed distinct patterns of lexical retrieval deficits when naming occurred in a semantic context (semantic interference). Precisely, here, we advanced that the extent to which PwA were susceptible to the semantic interference might play a crucial role to disentangle the locus where these deficits origin. Results showed that a subset of patients (Group 1) demonstrated an exaggerated effect of interference in terms of reaction times and omission errors, but not in terms of coordinate errors and within-set errors. This pattern of deficits was consistent with an exaggerated refractory state. That is, in the Group 1 the retrieval of a target word would cause the inhibition of its competitors below the activation threshold (Dell 1986; MacKay 1987; Forde and Humphreys 1997; Warrington and Crutch 2004; Forde and Humphreys 2013). However, in these patients the system is unable to bring the activation back to normal level. As a consequence, in this group, the successive retrieval of the semantic neighbours will be slower and more prone to omissions. Additionally, in the Group 1 the analysis of the temporal characteristic of omissions showed that this type of error decreased as a function of the time. We speculate that this result would support the transient nature of the refractoriness, i.e., long-time intervals would give the system more time to return to its activation baseline (Forde and Humphreys 1997; McCarthy and Kartsounis 2000; Forde and Humphreys 2013; Mirman and Britt 2014).

In contrast with the Group 1, another group of patients (Group 2) showed high interference in terms of coordinate and within-set errors, but not for reaction times and omissions. Furthermore, in the second group, within set errors were more likely to occurred in the immediately following trials and then, they decreased as a function of time. This pattern of lexical deficits was consistent with a lack of inhibition which resulted in a situation of "too much activation", i.e., an uncontrolled activation of both semantic neighbours and previously activated target words. In other words, in these patients, upon target retrieval, its activation and those coming from competitors would remain active for a given amount of time rather than being inhibited. Consequently, this residual activation competes with new target, especially when it belongs to the same semantic category, making the patients more prone to produce within-set and coordinate errors.

Finally, delta plot showed that semantic interference linearly increased in Group 1, whereas decreased in Group 2 across the quartiles. These last results were quite controversial. Shao et al. (2013, 2015; see also Ridderinkhof et al. 2005) attributed a linear increase of interference in the delta plot to the absence of an executive control inhibition. By contrast, they conceived the decrease of the interference as the effect of a top-down inhibitory mechanism which suppress the competitive responses. Coherently with this assumption, Group 2 was expected to show higher interference across quartiles, since their lexical deficits might be attributed to a damage of an external control mechanism. However, our results were inconsistent with this prediction. We offer three possible interpretations: a) the results could be an artefact of our grouping criterion (high vs low interference). Indeed, grouping patients on the semantic interference would bias the results in such an analysis. Furthermore, testing patients on the same variable used to group them make it somewhat tautological; b) consistently with some evidence (Costa et al. 2009; de Zubicaray et al. 2013; Riès et al. 2015; Rose and Abdel Rahman 2016), executive control mechanisms may not play a role in modulating semantic interference in a continuous picture naming. In this case, the easiest way to interpret our results would be that low latencies may emphasize the normal effect (e.g. the slower is the naming of a target, the higher or lower is the semantic interference); c) executive control suppression mechanisms have been thought to be triggered by an exaggerate activation of both target representation and its competitors. However, in Group 1 an exceeding refractoriness may not allow these mechanisms to be engaged. On the other hand, in Group 2 such a mechanism may be involved, but only act on reaction time (e.g. by modulating the activation threshold; see Ratcliff et al. 2004; Ratcliff 2008). In other words, these mechanisms might speed naming latencies, but increase the probability to make an error. In order to disentangle these last results, in the successive experiments we tested both the delta plots and the slope for the last quartile making two predictions: a) if our results were an artefact bound to the grouping criterion, they won't be present in those tasks in which our groups do not differ, especially in terms of reaction times; b) if our results could be explained by the absence or presence of executive control mechanisms, consistently with the idea that these mechanisms are somewhat general, the same pattern of results should be present in the other tasks in which it is necessary to suppress a dominant response (e.g. semantic probe and Stroop task).

Experiment 2

As discussed above, in the first experiment 1 two distinct clusters of lexical retrieval deficits emerged in PwA. Their distinct performance were thought to reflect either an abnormal refractoriness (Group 1) or an impairment of lateral inhibition (Group 2). Here we assessed the stability of PwA deficits in another task inducing semantic interference: cyclic blocking naming.

Method

Participants

A subset of our aphasic patients (N=11) performed this task, whereas 9 out of 20 did not because of early hospital discharges. All of previous HCs also performed the cyclic blocking naming.

Apparatus

The apparatus was the same as the experiment 1.

Experimental Task: Cyclic Blocking Naming

A set of 72 line-drawing pictures obtained from a variety of sources mad up the stimuli (Appendix 17). Pictures were blocked by semantic relatedness. The related blocks comprised of members from a semantic category, whereas the unrelated blocks were built using one member from each semantic category. There were 24 blocks (12 related and 12 unrelated) overall, 6 items for each, and items within a block were repeated 4 times (or 4 cycles). The order of stimuli/ blocks was controlled as follows. We ensured that items within a block occupied each ordinal position across the 4 cycles. The sequence of related vs unrelated blocks was pseudo-randomly ordered to ensure that no pattern of alternating blocks emerged (e.g., related, unrelated, related...etc.,). Typically, naming latencies reduce

with each cycle (due repetition priming). Furthermore, naming becomes slower when pictures are provided in related as compared to unrelated blocks.
Before performing the experimental task, participants familiarize with the stimuli. Firstly, the experimental pictures were displayed one at time by means of a booklet. Under each picture there was its correct label, in capital letters, in order to remove ambiguity and individual differences in naming. Then, the pictures were presented again one at time and participants were instructed to name them aloud. If all participants' responses were correct, they performed the task. In the experiment, participants were asked to name the pictures as fast and as accurately as possible. They were informed that the pictures were arranged in a series of blocks, and pictures within each block are repeated in no particular order. Participants were told that they will be indicated that a given block has been completed via a message on the computer screen. In order to initiate the next block, they should press any key on the keyboard. Each block began with a "ready?" message that disappeared after participant pressed a key on the keyboard. The stimuli were then presented and remained on the screen until the participant generated a response. A blank screen then appeared for 1000ms followed by an "End of block..." message requesting the participant to "Press any button to continue..." to the next block. As in continuous picture naming, near-synonyms were scored as correct. Responses were scored as error if the name was incorrect or no response was given. Furthermore, errors were classified as: "omission", "superordinate", not related, "within-set and outside-set coordinate errors.

Results

Overall Group

We carried out an analysis on reaction times to investigate a general difference in terms of semantic interference between PwA and HCs in the cyclic blocking naming task. For these analyses omitted or incorrect responses were excluded (HCs mean 0%; PwA mean 4%). Latencies below 250ms (false trigger) and above 3 standard deviations of the participants' overall mean (outliers) were also removed (HCs mean 3%; PwA mean 6%). Usually, in the cyclic blocking naming, latencies from the second cycle are faster than the first cycle (repetition priming). Importantly, naming latencies are higher in semantically related versus unrelated blocks (semantic interference). Thus, we ran a 2x2x4 ANOVA with Group (PwA, HCs) treated as a between factor and Block (Related, Unrelated) and Cycle (from 1 to 4) as within factors. The analysis highlighted a significant main effect of Group ($F_{1,22}$= 31.55, $p < .01$, n^2_p= .58) with higher reaction times in PwA (1527ms) than in HCs (756ms); the expected semantic interference effect, that is a significant main effect of Block ($F_{1,22}$= 4.12, p= .05, n^2_p= .15); and a significant main effect of Cycle ($F_{3,66}$= 9.21, $p < .001$, n^2_p= .29). Furthermore, the analysis showed a significant Block by Cycle interaction ($F_{3,66}$= 11.40, p

< .001, n^2_p= .34) and a significant Group by Block by Cycle Interaction ($F_{3,66}$= 4.9, p= .004, n^2_p= .18). However, the Group by Block Interaction ($F_{1,22}$= .66, p= .42, n^2_p= .02) and the Group by Cycle interaction ($F_{3,66}$= .92, p= .43, n^2_p= .04) were not significant (Figure 27, Table 13).

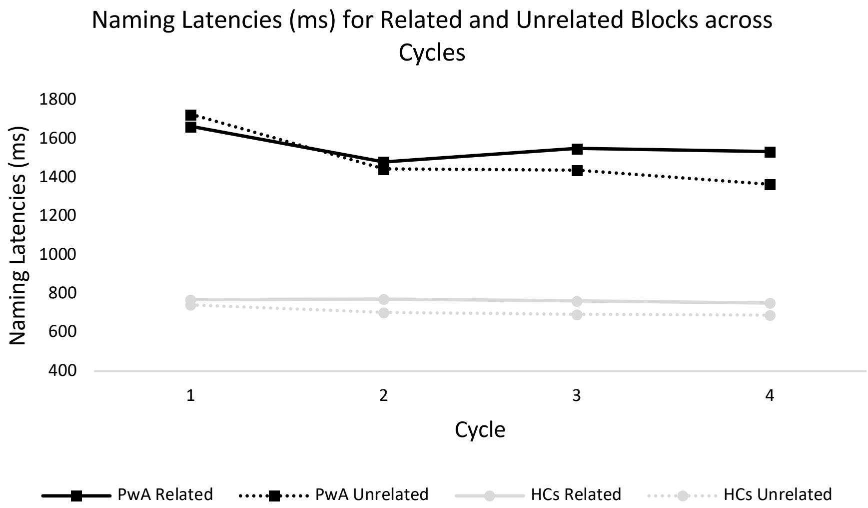

***Figure 27**. Naming latencies in related (continuous line) and unrelated (dotted line) blocks across cycles.*

***Table 13.** Naming latencies for related and unrelated blocks in PwA and HCs as a function of cycles. Standard error is reported in bracket*

		Cycle			
		1	2	3	4
PwA	Related	1667 (211)	1482 (125)	1552 (152)	1535 (141)
	Unrelated	1730 (232)	1448 (136)	1439 (138)	1367 (119)
HCs	Related	852 (21)	771 (16)	743 (16)	732 (13)
	Unrelated	864 (18)	728 (12)	701 (15)	692 (14)

Since PwA had higher response times than HCs, we recomputed response latencies for each participant as the ratio of RTs for all the conditions relative to the participant's overall RTs (hereafter referred to as Relative Reaction Times or RRTs). The aim of RRTs was twofold: a) to avoid that a general difference in terms of RTs could undermine further analyses; b) to maintain a coherent method of data analysis through all the tasks.

After computing RRTs for our experimental conditions, data were resubmitted to a 2x2x4 ANOVA. Results showed a significant main effect of Block ($F_{1,22}$=7.09, p= .01, n^2_p= .24); a significant main effect of Cycle ($F_{3,66}$=17.79, p < .001, n^2_p= .44) and a significant Block by Cycle interaction ($F_{3,66}$=12.07, p < .001, n^2_p= .35). Furthermore, results confirmed a non significant Group by Block interaction ($F_{1,22}$= .02, p= .87, n^2_p= .001). Despite the similar results, RRTs did not report a significant difference between groups ($F_{1,22}$= .26, p= .61, n^2_p=

.01) and a Group by Block by Cycle interaction ($F_{3,66}$= 2.32, p= .08, n^2_p= .09; see Figure 28, Table 14).

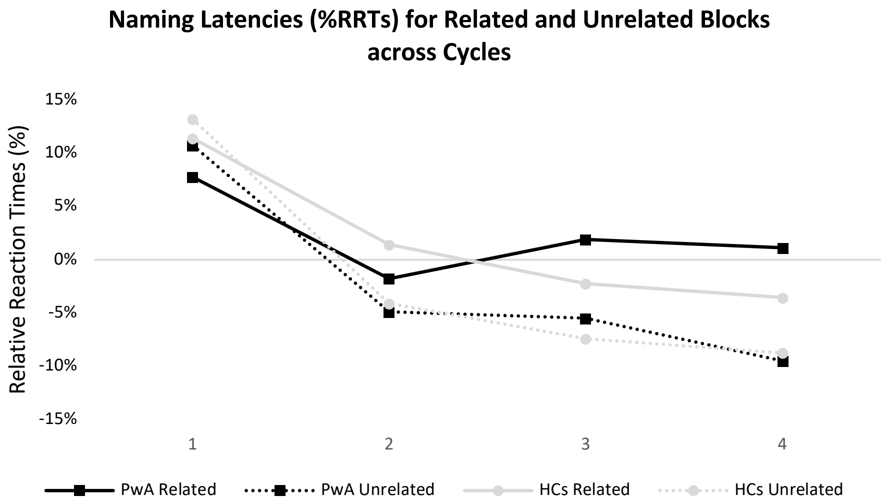

Figure 28. *Naming latencies in related (continuous line) and unrelated (dotted line) blocks across cycles.*

Table 14. *Relative reaction times for related and unrelated blocks in PwA and HCs as a function of cycles. Standard error is reported in bracket.*

		Cycle			
		1	2	3	4
PwA	Related	8% (4)	-2% (2)	2% (3)	1% (3)
	Unrelated	11% (5)	-5% (2)	-5% (2)	-10% (2)
HCs	Related	11% (1)	1% (1)	-2% (1)	-4% (1)
	Unrelated	13% (1)	-4% (1)	-7% (1)	-9% (1)

Crawford's Analysis

Subsequently, a Crawford analysis was carried out on the semantic interference index in order to test the reliability of our previous results. Semantic index was computed as the difference between the RRTs in the related blocks and those in the unrelated blocks. However, for this analysis the RRTs of the cycle 1 were excluded. The rational was that there is ample evidence that this cycle is overlaid by potentially strategic priming effects (Belke, 2017; Belke et al., 2017; also see table 13 and 14 above). With respect to this analysis, this implied that throwing cycle 1 and the remaining three cycles into one big analysis could gloss over the effect these important differences between cycles.

Results were rather consistent with those in the continuous picture naming. Indeed, in Group 1 the analysis showed that 5 patients out of 8 (the remaining 3 did not perform the task) had higher interference than HCs. Similarly, in Group 2 the analysis showed that 5 patients out of 12 (6 did not performed the task) had normal or lower semantic interference as compared to HCs. In Group 2, only patient (BC) had a higher semantic interference than HCs (Table 15). However, in order to explore a coherent pattern of results across tasks, BC was kept in the second group.

Table 15. *Results of Crawford Analysis. Patient's semantic interference score and the statistics for each comparison are provided.*

Participant	Group	Cumulative Semantic Interference Index (RRTs)	Single-case analysis on semantic index (Crawford & Howell, 1998)
AS	Group 1	10%	t(12)= 2.89; p= .01
BP	Group 1	9%	t(12)= 2.40; p= .03
CR	Group 1	14%	t(12)= 4.81; p < .001
OL	Group 1	11%	t(12)= 3.37; p= .006
SBK	Group 1	9%	t(12)= 2.40; p= .03
BC	Group 2	10%	t(12)= 2.89; p= .01
CM	Group 2	-4%	t(12)= -3.85; p= .002
CaS	Group 2	3%	t(12)= -0.48; p= .63
GM	Group 2	3%	t(12)= -0.48; p= .63
RP	Group 2	6%	t(12)= 0.96; p= .35
SC	Group 2	-20%	t(12)= -11.56; < .001
Healthy Controls	Controls	Mean= 4%; SD= 2%	________________

Patterns of Lexical Retrieval deficits in PwA Subgroups

Reaction times. Consistently with continuous picture naming, we wanted to explore the extent to which our subgroups showed different patterns of blocking interference. Thus, we carried out a 3x2x4 ANOVA with Group (Group 1, Group 2, HCs) treated as a between factor, and Block (Related, Unrelated) and Cycle (from 1 to 4) as within factors. Results confirmed a significant main effect of Block ($F_{1,21}$=14.29, p= .001, n^2_p= .40), a significant main effect of Cycle ($F_{3,63}$=21.88, p < .001, n^2_p= .51) and a significant Block by Cycle interaction ($F_{3,63}$=17.38, p < .001, n^2_p= .45). Furthermore, the analysis highlighted a significant Group by Block interaction ($F_{1,21}$=5.77, p= .01, n^2_p= .35), see Figure 29 and Table 16. A Bonferroni corrected post hoc comparison highlighted some differences between related and unrelated blocks for Group 1 (p < .001) and HCs (p= .02), but not for Group 2 (p > .05), see Figure 30. Consistently with the results in the continuous picture naming, Group 2 did not show the semantic interference in terms of RRTs.

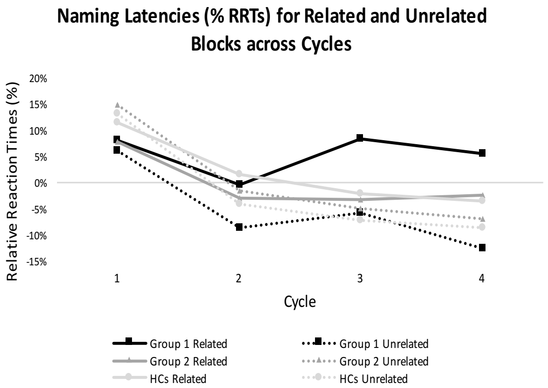

Figure 29. *Naming latencies in related (continuous line) and unrelatated (dotted line) blocks across cycles.*

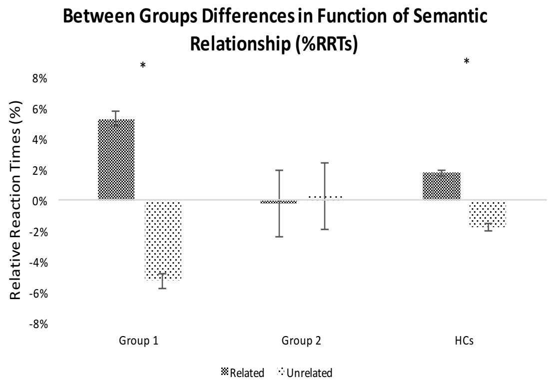

Figure 30. *The relative reaction times in function of blocks for PwA subgroups and HCs. Bars report standard errors. Asterisks highlight significant comparisons.*

Table 16. *RRTs and untreated RTs in PwA subgroups and HCs as a function of cycles. Standard error is reported in bracket.*

			Cycle			
			1	2	3	4
RRTs	Group 1	Related	8%(8)	0%(4)	8%(3)	5%(5)
		Unrelated	6%(9)	-9%(1)	-6%(3)	-13%(4)
	Group 2	Related	8%(3)	-3%(2)	-3%(3)	-2%(3)
		Unrelated	15%(4)	-2%(4)	-5%(4)	-7%(3)
	HCs	Related	11%(1)	1%(1)	-2%(1)	-4%(1)
		Unrelated	13%(1)	-4%(1)	-7%(1)	-9%(1)
Untreated RTs	Group 1	Related	1789(436)	1572(212)	1738(281)	1670(231)
		Unrelated	1783(474)	1463(231)	1491(209)	1367(156)
	Group 2	Related	1565(178)	1408(159)	1397(146)	1423(179)
		Unrelated	1685(214)	1436(181)	1395(200)	1366(189)
	HCs	Related	844(26)	767(19)	740(12)	729(11)
		Unrelated	856(19)	724(12)	700(15)	690(14)

Consistently with previous analysis, groups were compared in terms of repetition priming. The repetition priming index was computed by subtracting the RRTs in Cycle 1 to those in Cycle 2. This index was then submitted to a one-way ANOVA. Results did not report a significant difference between groups ($F_{2,21}$= .07, p= .93, n^2_p= .007) as shown in Figure 31.

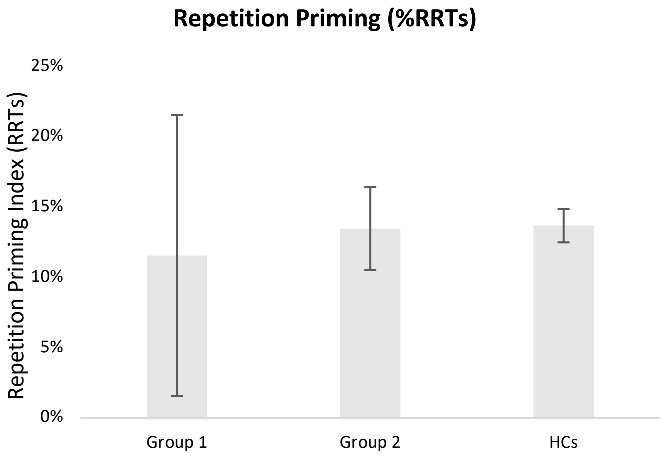

Figure 31. *The repetition priming index for PwA subgroups and HCs. Bars depict the standard error.*

Errors. A 3x2x4 ANOVA was carried out with Group as a between factor and both Block and Cycle as within factors. Errors only revealed a significant main effect of Group ($F_{2,21}$=16.55, p < .001, n^2_p= .61). Bonferroni corrected post hoc comparisons showed that HCs made less errors as compared to Group 1 (p= .02) and Group 2 (p < .001). However, no difference was found between Group 1 and Group 2. The analysis showed that the main effect of Block approached the significance ($F_{1,21}$= 3.28, p= .08, n^2_p= .13), while the main effect of Cycle ($F_{3,63}$= 1.29, p= .28, n^2_p= .05), the Block by Cycle ($F_{3,63}$= .93, p= .43, n^2_p= .04), Group by Block ($F_{2,21}$= .68, p= .51, n^2_p= .06), Group by Cycle ($F_{6,63}$= .34, p= .91, n^2_p= .03) and Group by Block by Cycle interactions ($F_{6,63}$= .37, p= .89, n^2_p= .03) were not significant, see Figure 32.

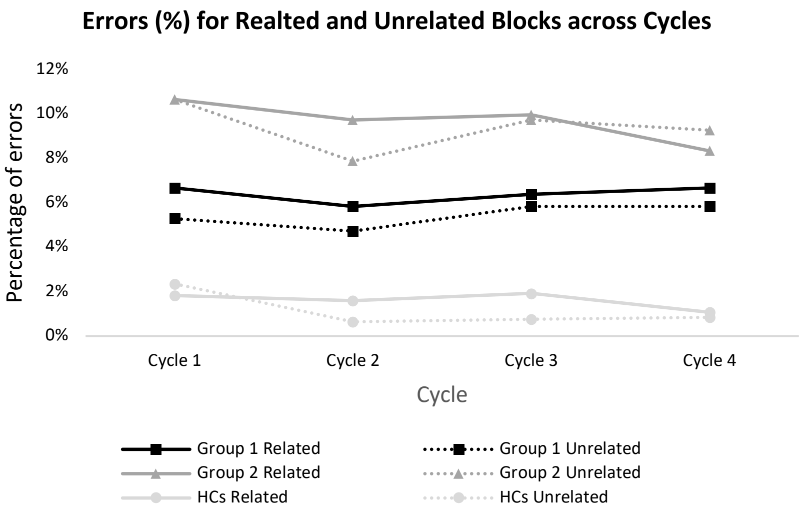

Figure 32. *Naming latencies in related (continuous line) and unrelated (dotted line) blocks across cycles.*

Error Types. Summarizing, the previous analyses confirmed a high semantic interference in Group 1 as compared to Group 2, with the latter showing a lack of interference, however no differences emerged for errors. Here we tested whether our PwA subgroups performance were stable in terms of error types. If lexical retrieval deficits in Group 1 and Group 2 were stable we would expect higher coordinate errors, especially within-set coordinate errors, in the latter group as compared with the former. For this analysis, omission, unrelated, outside-set and within-set coordinate errors were submitted to separate one-way ANOVAs. Comparisons were performed for all three groups, but for omissions, since controls did not make this type of error, they were excluded from the analysis. Results reported groups differed in terms of outside-set coordinate errors ($F_{2,21}$=10.85, p= .001, n^2_p= .50) and within-set coordinate errors ($F_{2,21}$=11.68, p< .001, n^2_p= .52). Bonferroni corrected post-hoc comparisons reported higher outside-set coordinate errors in Group 2 as compared to Group 1 (p= .02) and HCs (p < .001). Furthermore, Group 2 was more prone to produce within-set coordinate errors than Group 1 (p= .06) and HCs (p < .001), as shown in Figure 33.

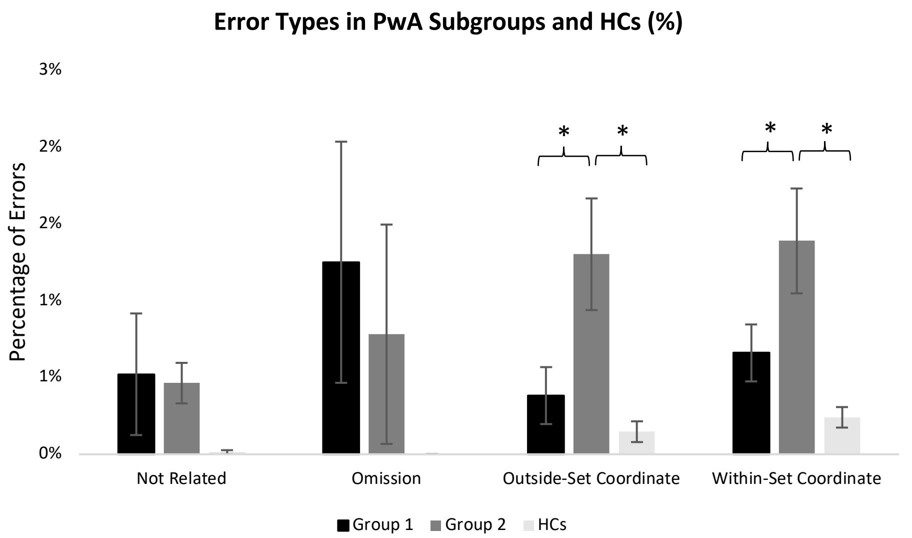

Figure 33. *Mean for each type of error. Bars report the standard error. The asterisks highlight the significant comparisons.*

Block Effect per Error Type. In the literature, aphasic patients have been described to produce more errors when naming occurs in a sematic context (McCarthy and Kartsounis 2000; Wilshire and McCarthy 2002; Schnur et al. 2006). Here, we predicted three different patterns of results for Group 1 and Group 2: a) in Group 1 the higher semantic interference in terms of naming latencies has been attributed to an abnormal refractoriness. Consistently with this hypothesis, patients in Group 1 should be more prone to omission errors when semantically related items were provided in a blocked fashion; b) in Group 2 performance should rely on a degradation of bottom-up inhibitory mechanisms (e.g. lateral inhibition), which results in a “too much activation”. Accordingly, we expected that in this group both outside-set and within-set coordinate errors were more likely to occur during the naming of blocks of semantically related items.

In order to investigate the first prediction, a first 2x2 ANOVA was carried out on omission errors with PwA subgroups as a between factor and Block as a within factor. As for the previous analysis, since throwing cycle 1 and the remaining three cycles into one big analysis could discard the differences between blocks we excluded this cycle from the analysis.

Results failed to report a significant main effect of Block ($F_{1,9}$= 0.1, p= .92, n^2_p= .14) and a significant Group by Block interaction ($F_{1,9}$= 1.50, p= .25, n^2_p= .14; Figure 34).

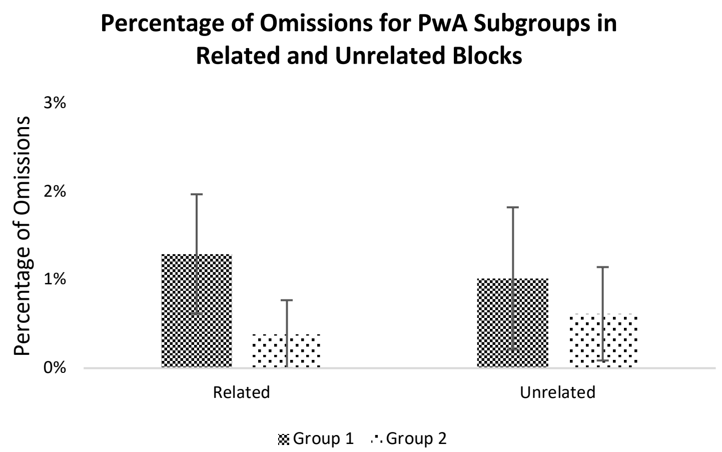

Figure 34. *Percentage of omission errors in PwA subgroups as a function of semantic context. Bars report the standard error.*

In order to test our second predictions, we carried out a 3x2x2 ANOVA with Group (Group 1, Group 2 and HCs) as a between factor and Type of Coordinate Error (Outside-set, Within-Set) and Block as within factors. The results showed a significant main effect of Type of Coordinate Error ($F_{1,21}$= 9.41, p= .006, n^2_p= .31), that is, within-set coordinate errors were more bound to occur than outside-set coordinate errors. Results also showed a significant main effect of Block ($F_{1,21}$= 9.03, p= .006, n^2_p= .31), i.e., all groups made more errors in “Related” blocks as compared to the “Unrelated” blocks. Interestingly, though results failed to highlight a significant Type of Coordinate Error ($F_{2,21}$= .90, p= .42, n^2_p= .07) and Group by Block interaction ($F_{2,21}$= .98, p= .38, n^2_p= .08), they reported a significant Group by Type of Error by Block interaction ($F_{2,21}$= 7.19, p= .004, n^2_p= .40; Figure 35). Bonferroni corrected post-hoc comparisons reported that Group 2 made more within-set errors in related blocks as compared to those produced by HCs in the same type of block (p < .001). Furthermore, in Group 2 within-set coordinate errors were more likely to occur in the related block as compared to unrelated block (p=.002). Particularly, in the former type of block within-set coordinate errors were more frequently produced than outside-set errors (p= .004).

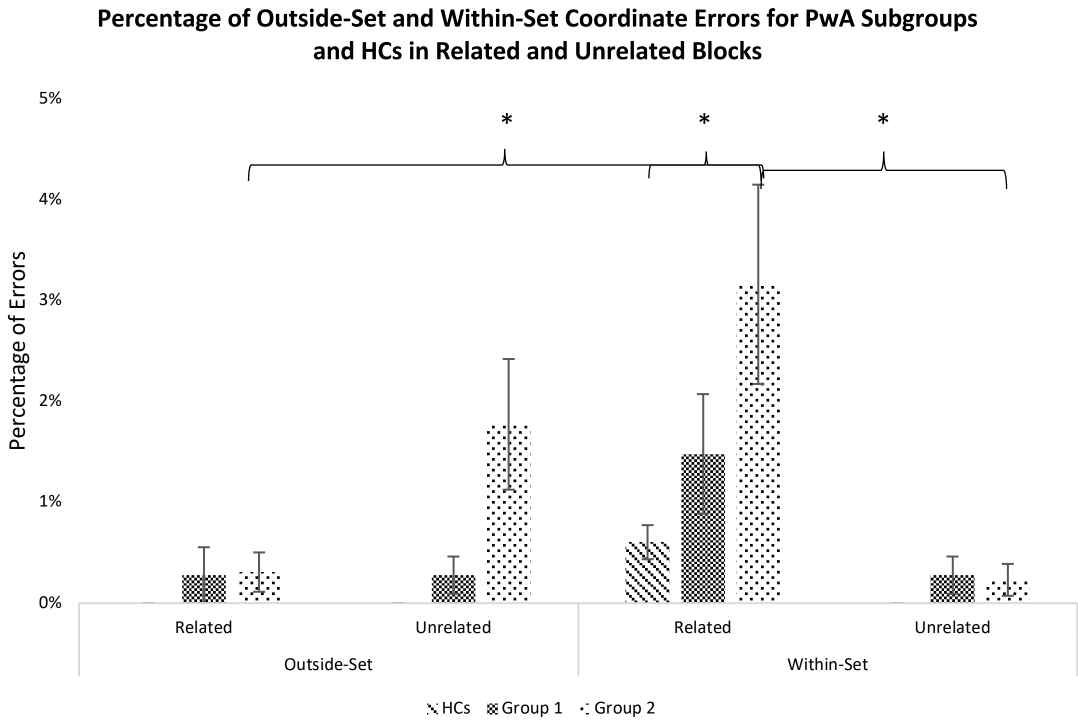

Figure 35. *Percentage of coordinate errors in PwA subgroups and HCs as a function of semantic context. Bars report the standard error.*

Though both figures (34 and 35 showed a pattern quite consistent with our hypothesis (higher omissions in Group 1 and coordinate errors in Group 2 in related blocks), these trends were not significant. In our opinion, these results may be affected by the previous training. Indeed, before performing the cyclic blocking naming, participants familiarized with the stimuli and performed the task only when they correctly named all the pictures. As far as we are concerned, the training would strengthen the connections between the picture and its correct label, reducing the number of omissions and coordinate errors. This idea was in line with the previous analyses on the overall percentage for each error type (see Figure 32). Indeed, in this study participants produced a small percentage of errors as compared to those in the continuous picture naming task (see Experiment 1).

Temporal Characteristics of Within-Set Errors. Group 2 showed a coherent pattern of lexical retrieval deficits in terms of error types: more within-set coordinate errors as compared to patients in Group 1 and HCs. Again, these results were in line with an uncontrolled activation of both semantic neighbours and previously activated target words in Group 2. Here we further tested the stability of lexical retrieval deficits in Group 2, by analysing the trend of perseverative responses (i.e. within-set errors) as a function of the interval between these errors and the original response. Consistently with Experiment 1, we assumed that Group 2 should be more prone to make within-set errors in the immediately following intervals and reduce their frequency as a function of the interval from the previous target trial. The replication of this result should contribute to support the idea that in Group 2 lexical retrieval deficits occurred as a damage to an inhibitory control mechanism.

As in the continuous picture naming, we merged the intervals between target word and within-set errors in 4 main intervals: 1 (from 1 to 3), 2 (from 4 to 6), 3 (from 7 to 9), 4 (higher than 10). Then, a 3x4 ANOVA was carried out with Group as a between factor and Interval (from 1 to 4) as a within factor. The results were consistent with those in the continuous picture naming. Indeed, they highlighted a significant main effect of Interval ($F_{3,63}$= 27.03, $p < .001$, η^2_p= .56) and a significant Group by Interval interaction ($F_{6,63}$= 9.44, $p < .001$, η^2_p= .47). In Group 2 within-set errors were more likely to occur in first intervals and then gradually decreased as a function of intervals (Figure 36).

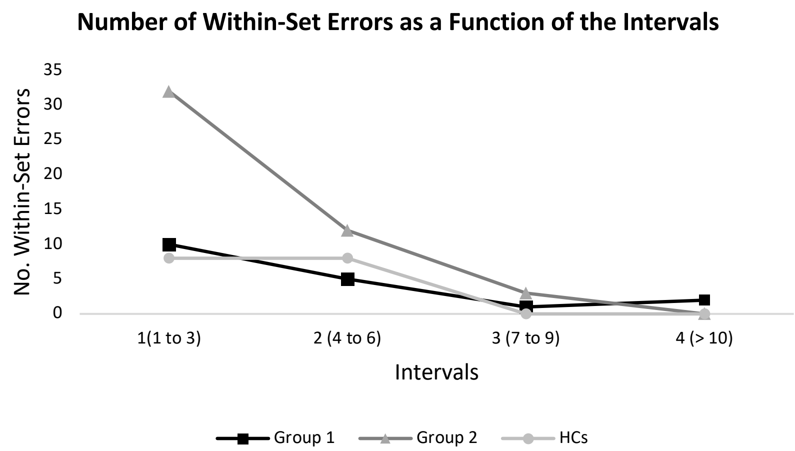

Figure 36. *Figure shows the number of within-set errors as a function of the distance between the perseverative response and its source.*

Executive Control Mechanisms in Naming. Finally, we investigated whether PwA subgroups showed coherent results in the delta plot and for the slope of the slowest quartile. As for the continuous picture naming, a 3x4 ANOVA was performed with Group as a between factor and the interference across quartile as a within factor. Then, a one-way ANOVA was performed with slope of the slowest quartiles as a dependent variable. The 3x4 ANOVA failed to show a main effect of Quartile but highlighted a significant Group by Quartile interaction ($F_{6,54}$= 2.71, p= .02, partial η^2_p = .23; Figure 37). Furthermore, the slope was significantly different among groups ($F_{2,18}$= 3.86, p= .02, partial η^2_p = .30) and a

Bonferroni corrected post hoc analysis showed that Group 1 had a higher slope than both Group 2 (p= .001) and HCs (p =.02). No difference was found between HCs and Group 2 (Figure 38). So far, the results replicated those in Experiment 1.

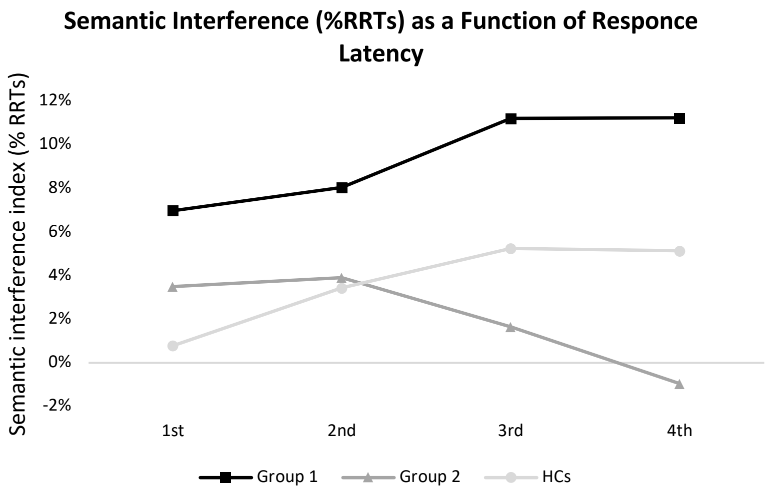

Figure 37. *The trend of semantic interference index as a function of quartiles.*

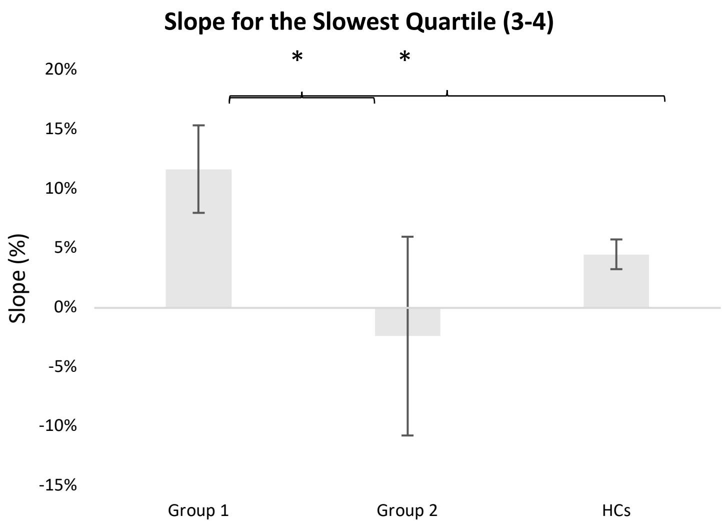

Figure 38. *The slope computed for the slowest quartile in PwA subgroups and HCs. Error bars report the standard errors. The asterisks highlight the significant comparisons.*

Discussion

In Experiment 2 we probed whether our patients showed similar patterns of lexical retrieval deficits in a cyclic blocking naming task. In the literature PwA's performance have been described as variable in terms of both omission and coordinate errors (Warrington 1975; Hodges et al. 1992; Laiacona et al. 1996; Lambon Ralph et al. 1998; McCarthy and

Kartsounis 2000). Furthermore, inconsistent findings have been also found in terms of semantic interference. For example, Schwartz and Hodgson (2002) described a patient (NQ) who was not affected by semantic context in a simple blocked naming task (just one cycle). Hodgson et al. (2003) replied this result in a cyclic blocking naming. However, in Schnur et al. (2006) the same patient showed a high semantic interference similar to Broca's patients.

Here, PwA's results confirmed two distinct patterns of lexical retrieval deficits: Group 1 showed higher interference in terms of reaction times. Furthermore, interference increased across the quartiles in the delta plot; Group 2 did not show semantic interference in terms of reaction times and distributional analysis highlighted a linear decrease of interference across quartiles. Consistently with Experiment 1, patients in the second group were more prone to produce outside-set and within-set coordinate errors as compared to Group 1 and HCs. Furthermore, within-set coordinate errors were more frequent in the immediately following trials and then decreased as a function of time.

Experiment 3

So far, PwA subgroups showed a coherent pattern of lexical retrieval deficits in both continuous picture naming and cyclic blocking naming tasks. In the present experiment, we aimed at investigating whether susceptibility to semantic context in PwA subgroups might be generalized to a short-term memory task (semantic probe), in which participants' performance is not verbal.

Method

Participants

14 of our 20 patients performed this task. All of previous HCs also performed the semantic probe task.

Apparatus

Stimuli words were displayed on a laptop computer screen (screen size: 15''), in uppercase, 56-point Times New Roman font. Stimulus presentation and response times were controlled by means of E-Prime 2 software. A practice session was provided in order to familiarize with task.

Experimental Task: Semantic Probe

A total of 120 word lists made up the experimental trials. In each trial list, five words were presented one at a time and followed by a probe word. Participants were asked to respond affirmatively if the probe was one of the previous five words (positive trials or positive probes) and negatively if not (negative trials or negative probes). In the present study, 60 trials out of 120 were negative trials whereas the remaining 60 were positive. Additionally, negative trials were split as follow: 40 trials contained items semantically related to each other and to the probe (No-Related); in the remaining 20 negative probe trials, the lists contained items that were not semantically related to each other nor to the probes (No-Unrelated). Previous studies (Hamilton and Martin 2007; Atkins and Reuter-Lorenz 2008; Atkins et al. 2011) have shown that latencies of false alarms (responding affirmatively to negative trials) and correct rejection (responding negatively to negative trials) were higher for the lists in which items were semantically related as compared to unrelated lists (semantic interference). On the other hand, no effects have been reported for positive probes. However, here we further split positive trials in related (items in the lists were semantically related to each other and to the probe; Yes-Related, N=30) and unrelated (words were not drawn from the same semantic category; Yes-Unrelated, N=30), to explore whether aphasics' performances might be affected by semantic relation even in probe trials.

At the beginning of each trial, a fixation cross was presented in the centre of the screen for 1000ms. This was followed by presentation of the list of words. Each word stayed on the screen for 400ms and was separated from the following word by a blank screen for 250ms. The probe remained on the screen until the participant gave a response. Participants gave "yes" and "no" responses by pressing the "g" and "j" keys, respectively. They were asked to respond as quickly and accurately as possible with the index finger of their left hand. Responses were provided by left hand (also by HCs) since our patients showed hemiparesis or hemiplegia of right hand as a consequence of CVA involving left hemisphere.

Results

General Susceptibility of PwA Subgroups to Semantic Context

Reaction times. For RTs analyses omitted or incorrect responses were excluded from the analyses (HCs mean 7%; PwA 17%). Latencies below 250ms (false trigger) and above 3 standard deviation (outliers) of the participant overall mean were removed (HCs mean 2%; PwA 2%). Latencies were higher in PwA than HCs (PwA 1904ms, HCs 1064ms; $F_{1,26}$= 15.31, p= .001, n^2_p= .37). Since PwA had higher response times than HCs, we recomputed response latencies for each participant as the ratio of the overall participant's RTs (hereafter referred to as Relative Reaction Times or RRTs).

In the semantic probe task, we aimed at investigating whether Group 1 and Group 2 showed a coherent pattern of behaviour even in a short-term memory task, that is, higher semantic interference in terms of RRTs in Group 1 and higher semantic interference in terms of errors in Group 2. Furthermore, if coordinate errors and perseverations in Group 2 occurred as a tendency to give an impulsive response, these patients should produce more false alarms in negative trials. In order to test these predictions, separate analyses were carried out for negative and positive trials. Semantic interference in both negative and positive trials was investigated by computing a semantic interference index. This index was estimated as a difference between the related and the unrelated condition and submitted to a one-way ANOVA. PwA subgroups as well as controls did not differ in terms of interference size in both negative ($F_{2,25}$= .83, p= .44, n^2_p= .06; Figure 39) and positive trials ($F_{2,25}$= 1.45, p= .25, n^2_p= .10; Figure 40).

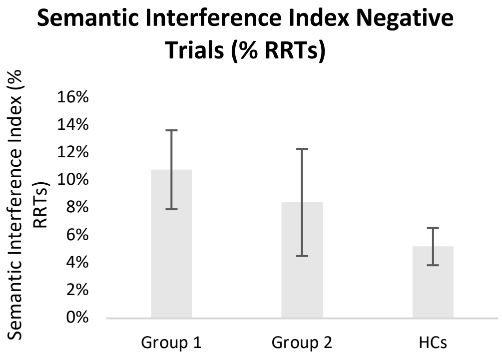

***Figure 39**. Semantic interference index in PwA subgroups and HCs. Bars depicted the standard error.*

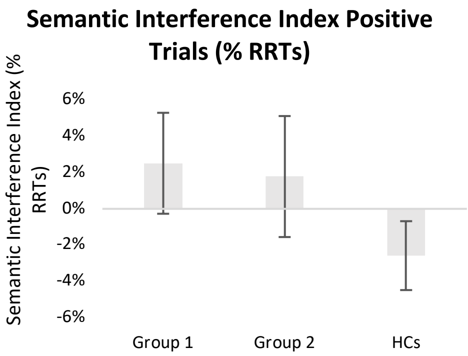

***Figure 40**. Semantic interference index in PwA subgroups and HCs. Bars depicted the standard error.*

Errors. Also for errors, two semantic interference indices were computed separately for the negative and the positive trials and submitted to a one-way ANOVA. Consistently with previous results, no significant comparison was highlighted either for negative ($F_{2,25}$= 1.04, p= .36, n^2_p= .07; Figure 41) or for positive trials ($F_{2,25}$= .65, p= .52, n^2_p= .05; Figure 42).

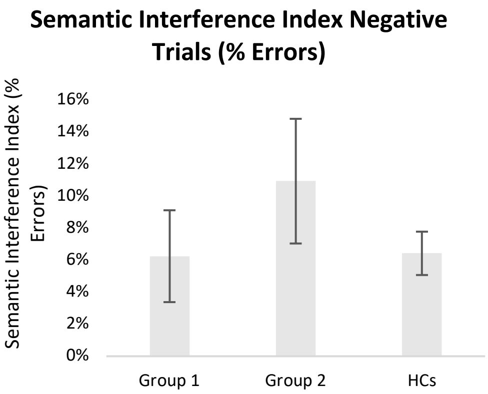

***Figure 41.** Semantic interference index in PwA subgroups and HCs. Bars depicted the standard error.*

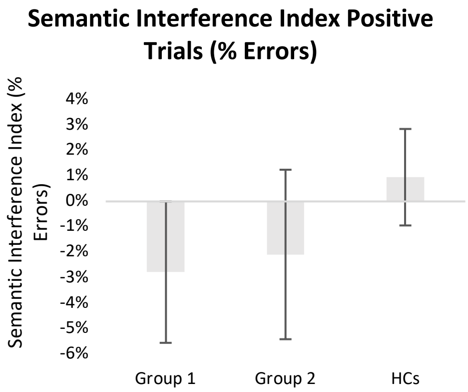

***Figure 42**. Semantic interference index in PwA subgroups and HCs. Bars depicted the standard error.*

Finally, we investigate the delta plot and the slope for the last quartile. As discussed earlier, the results of the delta plot and the slope in the previous two experiments might be either an artefact of our grouping criterion (high vs low interference) or the effects of some external control mechanism. Specifically, we advanced that if our results were an artefact, they would not be consistent for those tasks in which our groups do not differ, especially in terms of reaction times. On the other hand, if our results were affected by a kind of top-down control mechanism, the same pattern of results should be expected through all the tasks where it is necessary to suppress a dominant response, such as the semantic probe task. To test these predictions, a first 3x4 ANOVA was performed on the semantic interference index (%RRTs) in negative trials with Group as a between factor and Quartile as a within factor. Then, a one-way ANOVA was performed with slope of the slowest quartiles as a dependent variable. Here we analysed semantic interference in negative trials only, because in the literature, they are more prone to false alarms and correct rejections latencies when items are semantically related. The 3x4 ANOVA showed only a significant main effect of Quartile ($F_{3,75}$= 7.26, $p < .001$, partial $\eta^2_p = .48$), but did not highlight a significant Group by Quartile interaction ($F_{6,75}$= 1.71, p= .12, partial $\eta^2_p = .12$; Figure 43). The one-way ANOVA carried out on the slope also failed to report a significant difference among groups ($F_{2,55}$= .88, p= .42, partial $\eta^2_p = .06$; Figure 44).

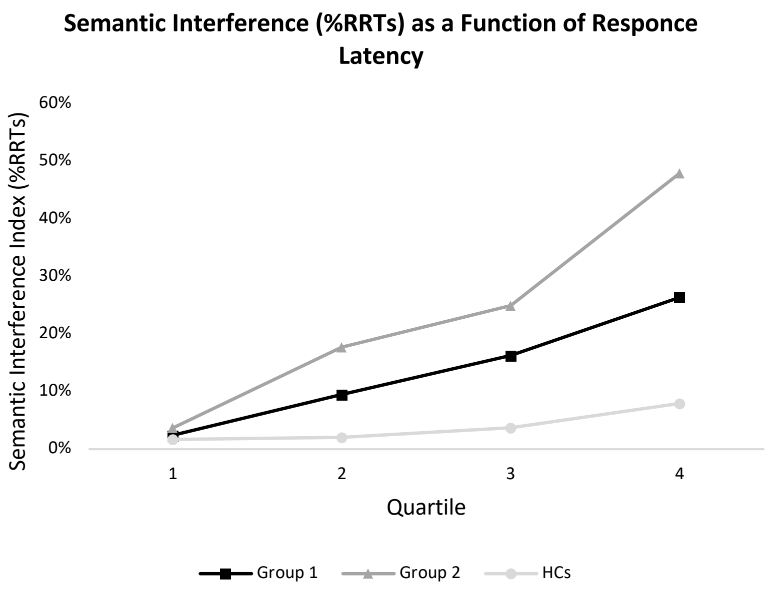

Figure 43. *The trend of semantic interference index as a function of quartiles.*

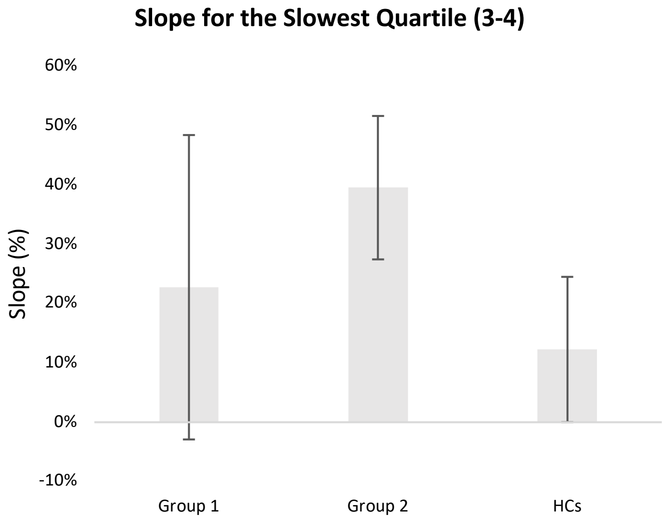

Figure 44. *The slope computed for the slowest quartile in PwA subgroups and HCs. Error bars report the standard errors.*

Discussion

Experiment 3 aimed to investigate whether PwA's performance was affected by the semantic context in a short-term memory task, in which no verbal response was requested. Recently, reduced short-term memory have been described in aphasia (Barde et al. 2010; Minkina et al. 2017 for a review). Short-term memory deficits in aphasic patients may play an important role in modulating the susceptibility of PwA to interference (Mahon et al. 2007). In the present study, we advanced that if the different susceptibility to the semantic context in our PwA subgroups was a quite stable trait, then it should be also replicated in a short-term memory task inducing semantic interference (semantic probe task). Furthermore, we advanced that in Group 2 higher false alarms for negative trials would occur as: a) a tendency to give an impulsive response (e.g. as a consequence of a damage to the external control mechanisms); b) a damage at the semantic rather than the lexical level.

The results, failed to highlight any significant difference, supporting the hypothesis that the differences between PwA subgroups relied on a damage at lexical rather than at the semantic level. Furthermore, delta plot results in Group 2 differed as compared to those in the first two experiments. Precisely, in this group semantic interference increased across quartiles. Additionally, the slope in the second group showed a higher score as compared to those in continuous picture naming and cyclic blocking naming of the same group. Bound together, these data supported the idea that results about both delta plot and slope in the previous two experiments might be an artefact of our grouping criterion.

Experiment 4

The aim of this experiment was twofold: a) to investigate whether our PwA subgroups showed a similar pattern of lexical deficits in another task where a dominant response needs to be suppressed; b) to investigate the extent to which the performance in Group 2 could be reliant on a damage of executive control mechanisms. These mechanisms have been thought to play an important role in those tasks, such as Stroop, PWI and cyclic blocking naming (Nigg 2000; Shao et al. 2013; Shao et al. 2014; Shao et al. 2015), where strongly competing responses are induced by distractors. Here we posited that if in Group 2 there was a degradation of one such mechanism, a higher Stroop effect would be expected for both reaction times and errors (see Table 5). Consistently with this goal, PwAs' and HCs' performances were compared in a Stroop task.

Method

Participants

15 of our 20 aphasic patients performed this task. All of previous HCs also performed the semantic probe task.

Apparatus

The apparatus was the same as Experiment 3.

Experimental Task: Stroop Task

Stimuli consisted of four colour words (BLUE, RED, YELLOW and GREEN) and string of Xs (i.e. "XXXX") printed in one of the four colours (blue, red, yellow and green). There were three main conditions (24 trials for each condition): neutral, congruent and incongruent. In the neutral condition, a string of Xs was shown in one of the four possible colours. In the congruent condition, colour words were provided in their corresponding colours. Finally, in the incongruent condition, colour words were presented with in one of the other three different colours (e.g. "RED" written with green ink).

Each trial started with a fixation cross presented at the centre of screen for 1000ms, followed by the either a word or a string of Xs. Stimuli remained on the screen until the participant gave a verbal response. Participants were instructed to name the ink of colour words (or Xs) as fast and accurately as possible.

Results

Executive Inhibitory Mechanisms in PwA Subgroups

Reaction Times. Omitted or incorrect responses were excluded from the analysis (HCs mean 1%; PwA mean 9%). Latencies below 250ms (false trigger) and above 3 standard deviation (outliers) of the participant overall mean were removed (HCs mean 2%; PwA mean 3%). Importantly, latencies were higher in PwA than in HCs (PwA 2265ms, HCs 1013ms; $F_{1,28}$= 11.61, p < .002, n^2_p= .29). Since PwA had higher response times than HCs, we recomputed response latencies for each participant as the ratio of RTs for all the conditions relative to the overall RTs (hereafter referred to as Relative Reaction Times or RRTs).

Subsequently, the Stroop effect was calculated as the difference between incongruent and congruent conditions and submitted to a one-way ANOVA. Results reported a significant difference between group ($F_{2,27}$= 7.71, p < .002, n^2_p= .36) and Bonferroni corrected post hoc comparisons showed higher Stroop effect in both Group 1 and Group 2 as compared to HCs (p= .003 and p= .05, respectively). Group 1 and Group 2 were not different (p= .75; Figure 45).

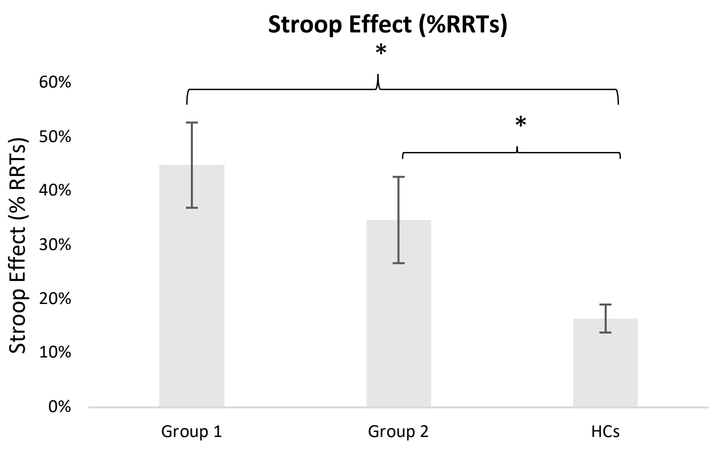

***Figure 45**. Stroop effect in PwA subgroups and HCs. Bars depict the standard error. Asterisks highlight significant comparisons.*

Errors. The Stroop effect was also estimated for errors and submitted to a one-way ANOVA. Results highlighted a significant effect of Group ($F_{2,27}$= 6.02, p < .007, n^2_p= .30). Bonferroni corrected post hoc comparisons highlighted a significant difference between Group 2 and HCs (p. = .006) but failed to report other significant comparisons (p > .05; Figure 46).

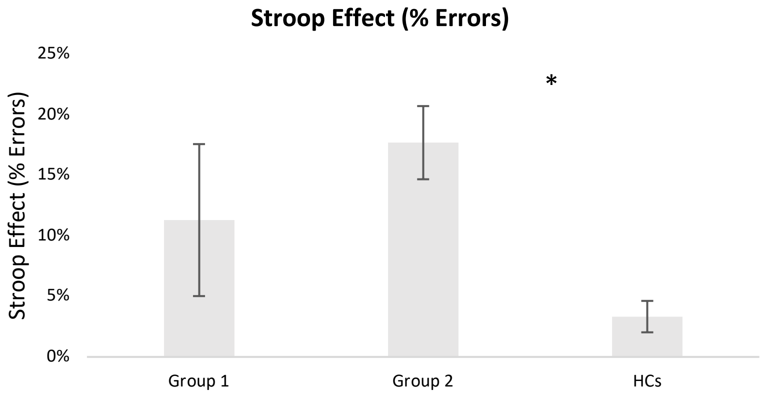

Figure 46. *Stroop effect in PwA subgroups and HCs. Bars depicted the standard error. Asterisks highlight significant comparisons.*

So far both reaction times and errors highlighted a similar pattern of results in Group 1 as compared to HCs, namely a higher Stroop effect in terms of latencies, but no difference in terms of errors. On the other hand, Group 2 showed a pattern of deficits consistent with a damage to executive control mechanisms: higher interference in terms of both reaction times and errors as compared to HCs (see Table 1). However, no statistical differences were highlighted between this group and Group 1.

Finally, as for the previous experiments, we investigated both delta plot and the slope for the last quartile. Accordingly, we carried out a 3x4 ANOVA with Group as a between factor and the interference across quartile as a within factor. Then, a one-way ANOVA was performed with slope of the slowest quartiles as a dependent variable. The 3x4 ANOVA showed a significant main effect of Quartile ($F_{3,78}$= 9.88, $p < .001$, partial $\eta^2_p = .27$) and a significant Group by Quartile interaction ($F_{6,78}$= 3.20, p= .007, partial $\eta^2_p = .19$; Figure 47). The one-way ANOVA carried out on the slope reported a significant difference among groups ($F_{2,29}$= 5.73, p= .009, partial $\eta^2_p = .30$) and Bonferroni corrected post hoc comparisons highlighted a significant difference of HCs as compared to Group 1 (p= .02) and Group 2 (p= .04) but no difference between PwA subgroups ($p > .05$; see Figure 48).

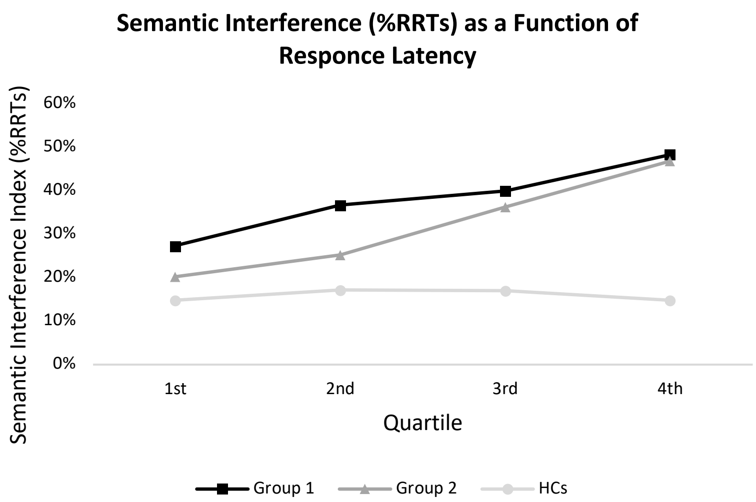

Figure 47. *The trend of semantic interference index as a function of quartiles.*

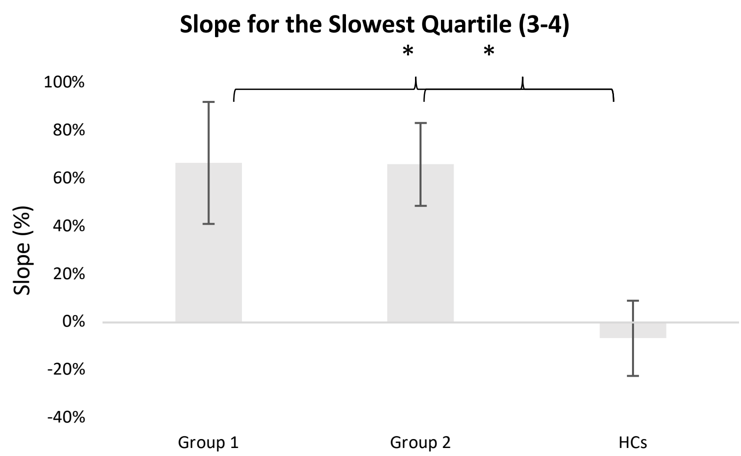

Figure 48. *The slope computed for the slowest quartile in PwA subgroups and HCs. Error bars report the standard errors. The asterisks highlight the significant comparisons.*

Discussion

Bound together the results in Group 2 were consistent with a damage of an external inhibitory mechanisms. Indeed, these patients showed higher Stroop effect in terms of reaction times and errors (Figure 45 and 46). Furthermore, Stroop effect showed a different trend across quartiles and the slope for the last quartiles was higher as compared to HCs (Figure 47 and 48). On the other hand, in Group 1 Stroop effect was higher as compared to HCs, but there was no difference in terms of errors. The trend of Stroop effect and the slope computed for the last quartiles were similar to those in Group 2. However, results in Group 1 (high interference in terms of latencies and its increase across quartiles) were quite coherent in all those tasks involving lexical retrieval, especially when it occurred amid competitors (continuous picture naming, cyclic blocking naming and Stroop task).

General Discussion

In the present study, we posited that a damage at the level of either bottom-up (activation, inhibition and priming) or top-down mechanisms (external control mechanisms) would lead to differences in terms of the amount of semantic interference as well as to distinct patterns of lexical retrieval deficits in aphasia. In the literature, different models (activation, inhibition, incremental learning and executive models) made distinct predictions about the patterns of deficits emerging after a brain damage. Importantly, these predictions vary consistently with the importance that these models attribute to one of the aforementioned mechanisms. Here, we extensively tested these predictions in different experiments in which we compared the performance of aphasic patients and healthy individuals in several tasks inducing semantic interference in naming (continuous picture naming task, Experiment 1; cyclic blocking naming task, Experiment 2) and recognition (semantic probe task, Experiment 3), and finally compared their overall ability to suppress a dominant response by means of a Stroop task (experiment 4). Bound together, our results can be interpreted as either an abnormal refractoriness (Group 1) or a lack of inhibition (Group 2) providing evidence for inhibition models. Here, we claim that such a model would be a good model to account for: a) lexical retrieval in healthy participants; b) the effect of semantic context in hampering lexical retrieval; c) distinct patterns of lexical retrieval deficits aphasia.

Chapter 5: General Discussion

In this final chapter all the main ideas from all the three experimental chapters are bound together and the results from each experiment are fully discussed in the light of the main models of lexical retrieval. Finally, I integrate the results from the previous study to discuss how my findings inform the working model proposed in the general introduction.

Cognitive styles modulate semantic interference

Our study investigated the nature of individual differences in semantic interference effects during lexical access. Semantic interference effects arise within the lexical system and are modulated by the efficacy of mechanisms which operate *within* the lexicon, such as mechanisms of lateral inhibition (Gurd and Oliveira 1996; Brown et al. 2005) which suppress the activation of competing words during lexical access, or alternatively by mechanisms which make the activation of representations return to baseline with passage of time (e.g. Schnur 2014). The question is whether interference effects are mediated mostly or exclusively by these in-house mechanisms or whether other mechanisms contribute as well. Interference could also be controlled by top-down inhibitory mechanisms which operate across modalities and tasks. Additionally, it is possible that some supra-modal individual characteristics -that can be referred to as cognitive styles- modulate the strength of interference effects across modalities. Our study addressed these possibilities.

The hypothesis that interference effects are controlled exclusively within the lexicon predicts that the strength of semantic interference in picture naming will be unrelated to the strength of interference effects in other tasks such as STM tasks and the Stroop. In the case of STM probe tasks, the effects of semantic interference will be controlled by mechanisms which efficiently clear the buffer of previous information and by the presence of a good phonological record which will counteract any semantic interference effect. These mechanisms/resources will be unrelated to mechanisms that control lexical selection among competitors. In the case of the Stroop, this task taps into the ability to respond to specific task demands by suppressing top-down more automatic responses. This ability can be strategically controlled and is also unrelated to the automatic mechanisms of selection operating within the lexicon. Alternatively, it has been argued that top-down inhibitory control can also play a role across tasks and, particularly, in picture naming in conditions of high elevated interference. For example, Schnur et al. (2006) stated that, "in line with the executive selection hypothesis, we now suggest that ''too much excitation'' among lexical-level competitors constitutes a signal that engages the executive selection mechanism; and that the latency effect [semantic interference] is due, in whole or in part, to the time needed for this mechanism to come on-line and/or affect the outcome of the competition" (pp. 220).

Our results provide some support for the hypothesis that effects of semantic interference are mostly lexically mediated. We have found no correlation between interference effects in picture naming and in STM probe tasks. In addition, we found no evidence that supra-modal inhibitory mechanisms modulate interference effects across tasks. We have found no correlation between interference in the Stroop task and interference in picture naming and probe tasks nor between interference in the Stroop task and scores on the embedded figures task (EFT). These results are consistent with an accumulating body of evidence arguing against such overarching mechanism of inhibitory control operating across tasks (Lang et al. 1995; Miyake et al. 2000; Friedman and Miyake 2004; Aron 2007; Munakata et al. 2011; Noreen et al. 2015; Shao et al. 2015). Different research lines have suggested a different nature for the control mechanism which operate within the lexicon and those which provide top-down task-specific control. We have already mentioned in the Introduction the different neuro-imaging correlates of interference effects in the Stroop and naming tasks and experiments by Dell'Acqua et al. (2007) indicating that control in lexical selection and the Stroop arises at different processing stages. Another example of a study showing differences between the interference effects in naming and in the Stroop is the study by Shao et al. (2015). These authors assumed that since selective inhibition takes time to deploy, it would operate more efficiently in trials where processing is slower, thus reducing interference for longer RTs (progressively less interference across RTs quartile; see also Ridderinkhof et al. 2005). They showed evidence of this reduction in interference in cyclic blocking and picture-word interference tasks, but not in the Stroop task. Discussing reasons for this difference is beyond the scope of this paper, but their results are consistent with ours in highlighting the differences between inhibitory mechanisms at play in picture naming and in the Stroop task.

Finally, our results provide support for the hypothesis that a general cognitive style related to the ability to separate stimuli from the background -field-dependency- influences semantic interference. We found a significant correlation between performance in an embedded figures task (measuring FI/FD) and semantic interference in the continuous picture naming task, and linear mixed models confirmed a contribution of field dependence/independence in accounting for variability in the interference effect in picture naming. This is an interesting and perhaps surprising result. It suggests that some individuals are more influenced by the context/reference framework in which stimuli are presented while others are better able to focus on discreet stimuli characteristics. We know that semantic similarity modulates the size of semantic interference in naming tasks (Vigliocco et al. 2002; Vigliocco et al. 2004; see also Alario and Martín 2010 for a similar conclusion). Field-dependent individuals would be more sensitive to this similarity. They would find difficult to overcome the perceptual context in which a simpler figure is embedded, but also to overcome the semantic context provided by a sequence of semantically related pictures in picture naming. FD individuals may adopt a "spectator approach" (Witkin et al. 1977) where, with each new stimulus of a category, the constant features of the category gradually become more salient, making it progressively more difficult to distinguish the identifying features of an item from 'background noise'.

The relationship between field dependency and semantic interference may be perceptually mediated. Semantic interference in picture naming may be mediated, at least in part, by visual similarity between items of the same category rather than by more abstract semantic similarity. Field dependent individuals may be more susceptible to this shared visual similarity and activate more strongly common features which, in turn, would make more difficult to select the specific features which identify the target. This explanation is consistent with our finding of a relationship between field dependency and the interference effect in picture naming, but not in the probe task. In the probe task, the stimuli are words rather than picture, making visual similarity less salient. On the other hand, there is evidence that the semantic interference in picture naming is not just a perceptual phenomenon, because it is also reported when items of the same category are visually distinct from one another (Rose and Abdel Rahman 2017), and for associative as well as for categorical relationships (Rose and Abdel Rahman 2016). Another possibility would be that field dependent individuals activate semantic fields where representations share features which are both perceptual in nature and more abstract. This more general semantic co-activation could also increase interference. To assess these alternatives, one should run continuous naming where the semantic categories include items which do or do not share visual similarity and see whether associations with measures of field dependency differ.

In conclusion, our results highlight the possibility that cognitive styles rather than general top-down executive control mechanisms modulate semantic interference effects in naming. We have shown that interference effects in picture naming are related to a cognitive style like field-dependency, but not to more general inhibitory mechanisms tapped by the Stroop task. Whether or the relationship between field-dependency and semantic interference effects is perceptually mediated should be investigated by further studies.

Longevity of semantic interference effect

The present study aimed at investigating the time frame (or longevity) of cumulative semantic interference. In the context of this study we took into account two main models as theoretical frameworks. On the one hand, SI has been conceived as resulting from a temporary activation of a previously selected word (residual activation account), which lasts for only a short interval. On the other hand, SI reflects persistent changes in the connections between conceptual and lexical entries (incremental learning account), which do not dissipate as a function of time. These approaches suggest two distinct predictions about the length of SI, respectively its decrease (residual activation account) or its persistence (incremental learning). We tested these predictions by means of two experiments in which: a) the sequence of related items in a continuous picture naming task was extended over the default number (Experiment 1); b) two parallel continuous picture naming lists were interspersed by a time interval of five minutes. During this time, semantic/lexical entries were not accessed (Experiment 2).

In the first experiment, the results showed a stabilization of cumulative semantic interference in the last ordinal positions in terms of reaction times. This result was supported by the interference index analysis, which confirmed a significant difference between the first and the second subset, i.e., higher semantic interference index in the first subset and a negative index in the second subset. Results in the second experiment, showed a linear increase of both naming latencies and errors in function of ordinal positions. Especially, reaction times showed a similar linear increase of SI in both lists with roughly the same gradient before and after the 5-minute gap (17ms, 14ms, respectively). Although we must be cautious in interpreting null results, they suggested that SI reset at baseline level after a given period of time.

As we reviewed in the Introduction, cumulative semantic interference has been reported to raise as a function of the naming of preceding members of the same semantic category (usually five) irrespective from the number (2, 4, 6, 8) of intervening items (Howard et al. 2006; Alario and Martín 2010; Navarrete et al. 2010). Since SI seems to be unaffected by the intervening stimuli, two recent computational models (Howard et al. 2006; Oppenheim et al. 2010) attributed this phenomenon to persistent changes in semantic/lexical connection weights (incremental learning). Howard et al. (2006), considered that upon naming an item (e.g. dog) its semantic to lexical connections are strengthened (priming), speeding the subsequent retrieval of the same word (repetition priming). However, the primed word (dog) can also act as a strong competitor, slowing the retrieval of a semantically related object (e.g. cat). Oppenheim et al. (2010) share the assumption that the correct naming of a given picture (e.g. dog) strengthens the connection between its respective semantic and lexical nodes. However, this model differs in the extent to which those connections that are not used, but semantically related to the named picture (e.g. cat, mouse) are weakened (or inhibited), hampering their successive retrieval. Despite the differences, these two models predict that SI is a result of persistent changes, which do not spontaneously dissipate and thus should persist for minutes (Howard et al. 2006; Nickels et al. 2008). Additionally, the incremental learning assumes that cumulative

semantic interference increases with relevant experience (see (Oppenheim et al. 2010), suggesting that it does not decay whether related items are protracted into a sequence.
However, bound together, our results are not consistent with the incremental learning's predictions. Indeed: a) SI did not cumulate unabated as a function of the related items in a sequence, but it vanished at some point (Experiment 1); b) SI did not persist after a relatively long-time interval (Experiment 2). Instead, they were more likely to rely on residual activation mechanisms. Consistently with these mechanisms, SI results from a residual activation from a previously retrieved information, which hampers the selection of a new target word. Importantly, residual activation is a temporary phenomenon, so it reset at pre-interference levels after a given time interval.
Our results were consistent with other studies which show that semantic interference may spontaneously decrease in function of time (Wheeldon and Monsell 1994; Schnur 2014). For example, Wheeldon and Monsell (1994) found that the production of a word elicited by a definition hampered the subsequent naming of a semantically related picture. This effect was stronger after a lag of 12s, but disappeared after several minutes (approximately 4 minutes), giving evidence that SI passively decreased somehow. Further evidence come from a study of Schnur (2014), in which the author demonstrated that cumulative semantic interference was modulated by lags and decayed when a small (8, 10, 12, 14) and large (20, 30, 40, 50) sequence of stimuli.
The idea that SI cannot increase indefinitely has also been investigated by Damian and Als (2005) by means of a cyclic blocking naming. The authors argued that: "... (SI) cannot be truly long lasting either... If semantic blocking effect spanned the entire experimental session, then all items should eventually have been blocked regardless of whether they were named in a homogeneous or a heterogeneous context. Clearly, this was not the case. It therefore appears as if the semantic context effect is reset between blocks or within a time interval roughly corresponding an experimental block" (p. 1381). Summarizing, the residual activation account offers a theoretical framework to interpret the results of the second experiment. Consistently with this view, the activation of previous targets persists for a short interval. During this time frame, those activated words act as strong competitors, hampering the retrieval of a semantically related object (SI). In the context of a continuous picture naming task, the constant access to semantically related entries (usually five) may result in the accumulation of their residual activations and hence a linear increase of competition: the residual activation coming from the first exemplar of a category will compete with the second related item, thus hampering its retrieval; the residual activation of the first two items will compete with the third and so forth. However, residual activation of the first items should decrease at some point. Accordingly, they no

longer contribute to SI, which in turn dissipates if the sequence of related items is protracted. Residual activation account also explained our results in the first experiment. Indeed, the dissipation of cumulative semantic interference allowed to reject the incremental learning account, suggesting that SI may rely on changes in residual activation rather than in semantic to lexical connections' weights. In conclusion, in the present study we argued that SI cannot increase indefinitely, but there must be a mechanism, in place to curtail the interference, otherwise future selection of other target words would become impossible. In the context of this study, residual activation mechanisms have been shown to offer those predictions that best fit with our data, giving a contribution to the understanding of the mechanisms underlie SI and lexical retrieval generally.

Different lexical mechanisms in the emergence of word retrieval deficits: Evidence from aphasia

Lexical retrieval has been conceived to rely on activation, inhibition, priming and executive mechanisms. These mechanisms play distinct roles in lexical retrieval and in the emergence of semantic interference, namely the slowing of lexical retrieval when it is conducted in the midst of semantically related objects. Given such complexity, we posited that a damage to one or more of these mechanisms would lead to specific patterns of deficits in lexical retrieval, especially when selection occurs in a semantic context.

Here we aimed at investigating these patterns. Precisely, we assessed whether a sample of patients with aphasia (PwA) showed a different susceptibility to semantic context in a continuous picture naming task (Experiment 1). Furthermore, in the same experiment we extensively explored different patterns of lexical retrieval deficits and to what extent the emergence of these deficits relied on a damage of activation, inhibition, priming and executive control mechanisms. By investigating the performance of our aphasic patients, in a cyclic blocking naming (Experiment 2), we sought to test the stability of the deficits highlighted in the Experiment 1. Since recent studies (Martin and Gupta 2004; Mahon et al. 2007; Barde et al. 2010; Potagas et al. 2011; Martin et al. 2012; Majerus et al. 2015; Minkina et al. 2017) report that the susceptibility to interference in aphasia may rely on a reduced short-term memory, we also investigated whether our patients showed coherent pattern of deficits also in a recognition task inducing semantic interference (semantic probe; Experiment 3). Finally, we attempted to find whether these distinct deficits could be attributed to a more general difference in the ability to suppress a dominant response, by comparing the performance of PwA subgroups in a Stroop task (Experiment 4).

In the literature, inconsistent findings have been reported about the size of semantic interference in aphasic patients. For example, some studies (Lambon Ralph et al. 2000; Gotts and Plaut 2002; Hodgson et al. 2003; Patient MO in Schnur et al. 2006) failed to report semantic interference in aphasic patients. On the other hand, some authors reported a semantic context-sensitivity in aphasic patients (McCarthy and Kartsounis 2000; Wilshire and McCarthy 2002; see Mirman and Britt 2014 for a review). In the Experiment 1, we posited that the extent to which patients were susceptible to semantic context, in terms of reaction times, would play a crucial role in disentangle the locus where distinct lexical retrieval deficits origin. Results showed two distinct patterns of lexical retrieval deficits in PwA. A subset of patients (Group 1) showed an exaggerated cumulative semantic interference in terms of reaction times and omissions. Furthermore, in this group omissions were time-bound, i.e., they decayed as a function of time. Distributional analysis (delta plot) showed a homogenous increase of interference across the whole distribution of response latencies. A second subset of patients (Group 2), on the other hand, showed high interference in terms of coordinate and within-set errors, but not for reaction times and omissions. In the second group, within-set errors were more likely to occur in the immediately following trials and then decreased as a function of time. Distributional analysis in this group highlighted a progressive reduction on interference across response latencies and a facilitatory effect of semantic relationship for the last two quartiles. In the second experiment the two PwA subgroups performed quite consistently with the previous experiment. That is, in a cyclic blocking naming task, Group 1 showed high semantic interference in terms of reaction times, whereas Group 2 did not. In PwA subgroups distributional analyses were coherent with the Experiment 1: linearly increase of interference in Group 1; progressive reduction in Group 2 (a facilitatory effect in last quartile). Additionally, patients in Group 2 were still more prone to make outside-set and within-set coordinate errors as compared to both Group 1 and HCs. As in Experiment 1, within-set coordinate errors in the Group 2 were more frequent in the immediately following trials and decreased as a function of time interval. In Experiment 3 we aimed to investigate whether PwA's performance was affected by the semantic context in a short-term memory task, in which no verbal response was requested. This experiment, failed to report any significant difference between Group 1 and Group 2, providing evidence that the previous patterns of deficits occurred only in lexical retrieval. Finally, in Experiment 4 we attempted to find whether these differences between Group 1 and Group 2 could be attributed to a more general difference in the ability to suppress a dominant response, by comparing their performance in a Stroop task. PwA subgroups did not differed in terms of both reaction times and errors, even though Group 2 showed a higher Stroop effect in terms of errors as compared to HCs.

As we reviewed in the *Introduction*, there are different models of lexical retrieval. These models differ in the extent to which they conceive lexical retrieval as more reliant on activation (activation models; Roelofs 1992; Levelt et al. 1999; Foygel 2000), inhibition (inhibition models; Harley 1993; Wheeldon and Monsell 1994; Chen and Mirman 2012), priming (incremental learning account; Howard et al. 2006; Schnur et al. 2006; Oppenheim et al. 2010) or executive mechanisms (executive control model; Thompson-Schill et al. 1997; Shao et al. 2013; Shao et al. 2015). Importantly, these models make different predictions about the lexical retrieval deficits that may emerge along with a high or low semantic interference after a damage to one or more of the aforementioned mechanisms (see Table 5). These predictions were tested in order to highlight the best model that fitted our data.

Activation vs Inhibition

Activation models posit that semantic interference emerges as an effect of the co-activation of a target and those words whose semantic specification is partly overlapping with the target (semantic neighbours). In other words, the target competes with its semantic neighbours and as a result it takes more time to reach an activation threshold. Consistently with this model, high semantic interference, in terms of latencies, may be expected as the result of an exceeding activation of nodes at the lexical level (i.e. "too much activation"). This situation would also lead to a higher semantic interference in terms of errors.

Our results in Experiment 1 and Experiment 2 did not fit with these predictions. In the continuous picture naming task, Group 1 showed a higher cumulative semantic interference in terms of reaction time and omissions. However, no cumulative interference was found for the other type of error. Furthermore, this group produced less outside-set and within set coordinate errors as compared to Group 2. This pattern of results was replicated in the cyclic blocking naming task. We argued that these results were inconsistent with the activation models but can be easily interpreted in an inhibition theoretical framework. Consistently with the inhibition models, lexical retrieval deficits Group 1 could be attributed to an abnormal refractory state. These evidence supported the findings from FAS patient presented by McCarthy and Kartsounis (2000). FAS' naming performances were adversely affected by semantic context, making more omissions in blocks of semantically related pictures as compared to unrelated blocks. The authors claimed FAS' omission to arise as a post-selection inhibition process involving both the lexical target node and its neighbours. Several studies showed that it would be feasible that a brain damage may prolong or exacerbate this inhibition (Forde and Humphreys 1997; Warrington and Crutch 2004; Crutch and Warrington 2007; Forde and Humphreys 2013; Mirman and Britt 2014). Furthermore, Gotts and Plaut (2002) implemented the abnormal refractoriness in a computational model of lexical retrieval. In this model, access deficits were implemented with a damage to neuromodulatory systems. Usually, the neuromodulatory systems, in a healthy brain, act to reduce the effect of inhibitory connections. Thus, a damage to such a system may result in: a) reduced sensitivity to input; b) increase of synaptic depression. “Together, these two effects produced a transient reduction to the degree to which inputs were able to activate semantic representations” (p. 6 Mirman et al., 2014).

The pattern of lexical retrieval deficits in Group 2 also supported the inhibition account. However, in contrast with Group 1, deficits in Group 2 can be conceived as relying on a damage to inhibitory connections, which results in a situation of “too much excitation”. In these patients, upon target retrieval, its activation and those coming from semantic neighbours would remain active for a given amount of time rather than being inhibited. Accordingly, residual activation would compete when a new target is presented, increasing the probability of outside-set and within-set coordinate errors. This prediction was corroborated by our results in Experiment 1. Indeed, in Group 2 these types of error increased with the presentation of each new category member. Furthermore, as we reported before within-set errors in Group 2 were more bound to occur in the immediate following trials. We posited that this result could emerge after a damage of the inhibitory mechanisms. A study by Campbell and Clark (1989; see also Campbell 1990, 1991) would support such interpretation. Indeed, they showed that the perseverative errors were, in healthy participants, during a naming task, in relation to the interval between these errors and original responses. They found that perseverations were reduced to the immediately following trials, suggesting a brief inhibitory effect. Thus, it might be feasible that the trend of perseveration errors in Group 2 was caused by a damage to inhibitory mechanisms.

In Experiment 1 and Experiment 2, reaction times analyses gave further evidence for inhibition models and against activation models. As we discussed earlier, activation models predict high semantic interference in terms of both reaction times and errors. In contrast with this prediction, Group 2 showed high semantic interference in terms of coordinate and perseveration errors, but no semantic interference in terms of reaction times. Furthermore, distributional analysis highlighted a linear decrease of interference across quartiles, with a facilitatory effect in the last quartile. These evidence were consistent with a study of Arnott et al. (2010) (see also Gurd and Oliveira 1996; Copland 2003). The authors sought to investigate the semantic interference in a group of patients with Parkinson Disease (PD) in a word-search task (Neisser & Beller, 1965). In such a task, participants searched word lists for either a particular target, e.g. lion or for a member of a target semantic set, e.g., any animal. Importantly the background items were either semantically related or unrelated. Results revealed that control participants showed slower responses for related vs unrelated word lists (semantic interference). In contrast, the PD group recorded no difference between word lists. Arnott and colleagues stated that their findings were consistent with the notion of decreased lateral inhibition in PD and suggest that an impaired ability to inhibit unwanted information during lexical retrieval may underlie observed deficits in semantic tasks.

In conclusion, bound together our results in the Experiment 1 and Experiment 2 supported the predictions advanced by the inhibition models, rejecting those advanced by the activation models.

Priming Mechanisms: The Incremental Learning Account

As we reviewed in the *Introduction*, incremental learning models assume semantic interference as relying on the strengthening (or weakening; see Oppenheim et al. 2010) of semantic to lexical connections (priming) which contributes to increase semantic interference. These models are quite similar to activation/inhibition models. However, they differ in the extent to which the results are attributed to more permanent mechanisms (incremental learning). Hence, the incremental learning models, posit activation or inhibition as a persistent rather than as a temporary phenomenon. In the context of this study we advanced two predictions consistently with the incremental learning model: a) the different types of errors (coordinate, within-set errors and omissions) should not decay as a function of time; b) priming mechanisms would lead to an increase of semantic interference in terms of coordinate errors and perseverations. In other words, the naming of a category exemplar (e.g. dog) may result in the strengthening of its semantic-to-lexical connections (e.g. Howard et al. 2006; Schnur et al. 2006; Hsiao et al. 2009; Oppenheim et al. 2010; Schnur 2014), making that word a primary candidate when the same category is activated by a related item (e.g. cat). In Experiment 1 our results supported the first prediction. Indeed, in Group 2 higher outside-set and within-set coordinate errors were associated to a higher repetition priming as compared to HCs. However, our results failed to report long-lasting effects for the errors: significant decrease of within-set errors in the Group 2; decrease of omissions in the Group 1. Though the decrease of omissions in Group 1 did not reach significance, here we speculate that our findings provided evidence for the transient nature of the inhibition/refractoriness, consistently with the inhibition models.

Executive Control Models

In the literature, it is still unclear whether executive mechanisms play a role in lexical retrieval (e.g. Costa et al. 2009; Riès et al. 2015). For example, in Levelt et al. (1999 see also Roelofs 1992; Roelofs 1997; Dell et al. 1999) the selection of a given word occurs when "an active lexical concept spreads some of its activation to its lemma node, and lemma selection is a statistical mechanism, which favours the selection of the highest activated lemma" (p. 4). Hence, in such a model lexical selection is modulated by mechanisms internal to the semantic/lexical system. On the other hand, some authors argue that when the lexical/semantic system experiences interference or a weak activation of any potential target, executive control mechanisms can be engaged in order to dissipate such interference (Ridderinkhof et al. 2005; Jefferies et al. 2007; Bedny et al. 2008; Schnur et al. 2009; Whitney et al. 2011; Shao et al. 2013; Krieger-Redwood and Jefferies 2014; Mirman and Britt 2014). In the present study, we advanced different predictions about the emergence of specific patterns of deficits following a damage to these external control mechanisms. Precisely we posited: a) a high interference in terms of reaction times and errors in naming tasks inducing semantic interference (see Wilshire and McCarthy 2002; Schnur et al. 2006; Schnur et al. 2009); b) higher reaction times and errors in other tasks in which a dominant response need to be suppressed (semantic probe or Stroop task; see Incisa et al. 1993; Shimamura et al. 1995; Mangels 1997; Telling et al. 2010); c) increase of interference on slower responses (delta plot and slope).

As we discussed earlier, Experiment 1 and Experiment 2 did not confirm the first predictions. Additionally, in Experiment 3 we failed to observe a difference between Group 1 and Group 2. By contrast, results of Group 2 in Experiment 4 were consistent with a damage to an external inhibitory mechanism. Indeed, these patients showed a higher Stroop effect in terms of reaction times and errors. Furthermore, the Stroop effect showed a different trend across quartile and the slope for the last quartile was higher as compared to HCs. These data suggested a damage of executive control mechanisms along with a damage at the lexical level.

In the context of this study we cannot exclude a damage to external control mechanisms in Group 2. However, we should be cautious in interpreting these results. Indeed, it might be feasible that lexical retrieval deficits, arose in the first two experiments, would contribute in modulating the results in Stroop task, somehow. Thus, here future studies need to be carried to shed light for a better understanding about on the role of executive processes in lexical retrieval.

An inhibition model of lexical retrieval: evidence from typical adults and aphasic patients

In the general introduction different models of lexical retrieval have been taken into account. Specifically, we focused on the mechanisms posited by each model and the degree to which these mechansims may hamper the correct retrieval of a target word in both healthy population and aphasic patients. We focused on three main models: a) activation models, in which a temporary jolt of activation is thought to cascade down, via spreading of activation, from semantic nodes to lexical entries. According to such a model, the retrieval of a target word happens when its lexical node overcomes a given activation threshold; b) inhibition models, which are similar to the activation models, but they also advance the prensence of bidirectional inhibitory connections in which the unit that becames active temporary dampened down its competitors at the same level; c) incremental learning models which include a more permanent modification of lexical-semantic connections following the experience. In these models, lexical selection should not be modified by passage of time alone.

In the general introduction I proposed a working model that share its main features with the traditional inhibition models (Chen and Mirman 2012; Harley and MacAndrew 1992; Harley 1993a; Harley 1993b; Dell & O'Seaghdha 1994). This model has been conceived as a working model within which to frame my experiments.

In the first study (Second Chapter), we found that field-dependent individuals were more sensitive to semantic similarity, showing a higher semantic interference as compared to field-independent individuals. These results are quite consistent with our working model. Indeed, in field-dependent individuals the constant features of the category gradually become more salient, making it progressively more difficult to distinguish the identifying features of an item from 'background noise'. This should induce a higher activation of both the target and its neighbours at semantic level, which in turns deploy a greater inhibiton of semantic competitors at lemma level (e.g. via spreading of inhibition), resulting in higher semantic interference. However, we should be quite cautious in interpreting these results, since they may be also consistent with an activation account (see for example Roelofs 1992; Levelt et al. 1999). That is, during the picture naming task, a target picture may activate both the target representation and its semantic neighbours at semantic level. This activation should flow down at lexical level causing the co-activation of the target word and its competitors, which in turns hamper the retrieval of the correct word.

In the second study (Third Chapter), I found that activation dissipates after an unfilled delay and that the strength of interference tapers off after presentation of distractors. These results are also coherent with my working model, since, in this model inhibition as been conceived as a temporary phenomenon, which dissipates as a function of time. However, as for the first experiment we should be cautios since also the activation models (Dell et al. 1997; Roelofs 1997; Dell et al. 1999; Levelt et al. 1999; Foygel 2000) posited a temporary activation, which decreases as a function of time.

Results in the third study (Fourth Chapter) are less ambiguous since they well fit with the predictions arisen by the inhibition models. Indeed, we found that Group 1 showed a higher cumulative semantic interference in terms of reaction time and omissions. However, no cumulative interference was found for the other type of error. Furthermore, this group produced less outside-set and within set coordinate errors as compared to Group 2. This pattern of results was replicated in the cyclic blocking naming task. We argued that these results were inconsistent with the activation models but can be easily interpreted in an inhibition theoretical framework. Consistently with the inhibition models, lexical retrieval deficits Group 1 could be attributed to an abnormal refractory state. Furthemrore In Experiment 1 our results supported the first prediction. Indeed, in Group 2 higher outside-set and within-set coordinate errors were associated to a higher repetition priming as compared to HCs. However, our results failed to report long-lasting effects for the errors: significant decrease of within-set errors in the Group 2; decrease of omissions in the Group 1. Though the decrease of omissions in Group 1 did not reach significance, here we speculate that our findings provided evidence for the transient nature of the inhibition/refractoriness, consistently with the inhibition models.

In conclusion, the inhibition model proposed in this thesis well fit with the results of my experiments. Furthermore, it offers an interesting theoretical framework to a better understanding of the mechanisms underlie lexical retrieval, their role in the semantic interference and the emergence of lexical retrieval devicits when these mechanisms break down, for example after a brain injury.

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Appendices

Appendix 1 Stimuli for Continuous Picture Naming.

Body Parts: arm (braccio), ear (orecchio), foot (piede), hand (mano), leg (gamba)

Clothing Items: dress (vestito), shirt (camicia), skirt (gonna), sweater (maglione), trousers (pantaloni)

Fruits: banana (banana), pineapple (ananas), strawberry (fragola), grapes (uva), pear (pera)

Furniture: chair (sedia), sofa (divano), desk (scrivania), table (tavolo), bed (letto)

Insects: butterfly (farfalla), spider (ragno), fly (mosca), ant (formica), mosquito (zanzara)

Instruments: drum (tamburo), trumpet (tromba), violin (violino), guitar (chitarra), piano (pianoforte)

Kitchen Utensil: pan (padella), knife (coltello), fork (forchetta), spoon (cucchiaio), plate (piatto)

Plants: flower (fiore), leaf (foglia), palm tree (palma), tree (albero), cactus (cactus)

Tools: hammer (martello), pliers (pinze), saw (sega), drill (trapano), screwdriver (giravite)

Transport: aeroplane (aereo), car (auto), train (treno), motorbike (moto), boat (barca)

White Goods: toaster (tostapane), blender (frullatore), refrigerator (frigorifero), washing machine (lavatrice), radio (radio)

Zoo Animals: elephant (elefante), panda (panda), monkey (scimmia), gorilla (gorilla), giraffe (giraffa)

Appendix 2 Stimulus statistics for the continuous picture naming tasks; frequency and length from CoLFIS database (Goslin et al. 2014).

	Position										Total	
	1		2		3		4		5		M	SD
	M	SD	M	SD	M	SD	M	SD	M	SD		
Frequency	51	40	52	74	70	70	50	49	64	60	58	59
Length	7	2	6	2	7	2	7	2	7	2	7	2

Appendix 4 Mean scores and variability (standard deviation) for each interference index and EFT.

	CPNI	Interference Associated	Interference Combined	Interference Associated+Combined	Interference Related	EFT
Mean	93	86	119	102	9	35
Standard Deviation	128	117	125	108	58	22

Appendix 4 Linear mixed models: Continuous picture naming task (a). CPN-m1 investigates the main effect of ordinal position (1 to 5), namely a cumulative semantic interference effect. CPN-m2 probes the main effect of both ordinal position and cognitive style (FI/FD). CPN-m3 tested the interaction between ordinal position and cognitive style, that is the modulation of the cumulative semantic interference by cognitive styles. In all three models, participants were treated as a random effect. Table shows information and statistics for each model.

Model	**Fixed Factor**	**Fixed Factor Statistics**		**Model's Statistics**			
		F	p	AIC	BIC	r^2_m	r^2_c
CPN-m1	Ordinal Position	73.98	< .001	- 432	- 418	.09	.67
CPN-m2	Ordinal Position	73.98	< .001	- 440	- 422	.20	.68
	EFT Score	10.23	.002				
CPN-m3	Ordinal Position	5.09	.02	- 446	- 425	.21	.69
	EFT Score	0.81	.36				
	Ordinal Position x EFT Score	8.42	.004				

Appendix 5 Linear mixed models: Continuous picture naming task (b). CPN-m1b investigates the main effect of ordinal position (1 to 5), namely a cumulative semantic interference effect. CPN-m2b probes the main effect of both ordinal position and cognitive style (FI/FD). CPN-m3b tested the interaction between ordinal position and cognitive style, that is the modulation of the cumulative semantic interference by cognitive styles. In all three models, the slope of the ordinal position was allowed to be different for each participant. Table shows information and statistics for each model.

Model	Fixed Factor	Fixed Factor Statistics		Model's Statistics			
		F	p	AIC	BIC	r^2_m	r^2_c
CPN-m1b	Ordinal Position	65.27	< .001	- 436	- 415	.09	.68
CPN-m2b	Ordinal Position	68.60	< .001	- 440	- 415	.15	.67
	EFT Score	6.05	.01				
CPN-m3b	Ordinal Position	4.80	.03	- 446	- 417	.21	.69
	EFT Score	1.06	.30				
	Ordinal Position x EFT Score	7.90	.006				

Appendix 6 Linear mixed models: Stroop task. ST-m1 investigates the main effect of Stroop condition (Congruent, Incongruent, Neutral), namely the Stroop effect. ST-m2 probes the main effect of both Stroop condition and cognitive style (FI/FD). ST-m3 tested the interaction between Stroop condition and cognitive style, that is the modulation of Stroop effect by cognitive styles. In all three models, participants were treated as a random effect. Table shows information and statistics for each model.

Model	Fixed Factor	Fixed Factor Statistics		Model Statistics			
		F	p	AIC	BIC	r^2_m	r^2_c
ST-m1	Stroop Condition	134.98	< .001	- 3345	-3314	.12	.50
ST-m2	Stroop Condition	134.98	< .001	- 3345	-3308	.12	.50
	EFT Score	1.96	.16				
ST-m3	Stroop Condition	36.93	< .001	- 3343	-3300	.12	.50
	EFT Score	1.96	.16				
	Stroop Condition x EFT Score	.07	.92				

Appendix 7 Linear mixed models: Semantic probe, negative trials (No-Associated and No-Unrelated). SPna-m1 investigates the main effect of the two negative probe conditions (Associated and Unrelated), namely a semantic interference effect. SPna-m2 probes the main effect of both negative probe conditions and cognitive style (FI/FD). SPna-m3 tested the interaction between negative probe conditions and cognitive style, that is the modulation of semantic interference effect by cognitive styles. In all three models, participants were treated as a random effect. Table shows information and statistics for each model.

Model	Fixed Factor	Fixed Factor Statistics		Model Statistics			
		F	p	AIC	BIC	r^2_m	r^2_c
SPna-m1	Negative Probe Condition	32.48	< .001	- 78.05	- 67.88	.03	.88
SPna-m2	Negative Probe Condition	32.48	< .001	- 78.81	- 66.09	.08	.88
	EFT Score	2.71	.10				
SPna-m3	Negative Probe Condition	9.6	.003	- 76.81	- 61.55	.08	.88
	EFT Score	2.71	.10				
	Negative Probe Condition x EFT Score	.0005	.98				

Appendix 8 Linear mixed models: Semantic probe, negative trials (No-Combined and No-Unrelated). SPnc-m1 investigates the main effect of the two negative probe conditions (Combined and Unrelated), namely a semantic interference effect. SPnc-m2 probes the main effect of both negative probe conditions and cognitive style (FI/FD). SPnc-m3 tested the interaction between negative probe conditions and cognitive style, that is the modulation of semantic interference effect by cognitive styles. In all three models, participants were treated as a random effect. Table shows information and statistics for each model.

Model	Fixed Factor	Fixed Factor Statistics		Model Statistics			
		F	p	AIC	BIC	r^2_m	r^2_c
SPnc-m1	Negative Probe Condition	47.07	< .001	- 66.11	- 55.94	.08	.83
SPnc-m2	Negative Probe Condition	47.07	< .001	- 67.57	- 54.85	.13	.84
	EFT Score	3.43	.07				
SPnc-m3	Negative Probe Condition	11.78	.001	- 65.73	- 50.47	.13	.83
	EFT Score	3.43	.07				
	Negative Probe Condition x EFT Score	.15	.69				

Appendix 9 Linear mixed models: Semantic probe, with averaged Associated and Combined negative trials. SPn_{A+C}-m1 investigates the main effect of the two negative probe conditions (Associated + Combined, Unrelated), namely a semantic interference effect. SPn_{A+C}-m2 probes the main effect of both negative probe conditions and cognitive style (FI/FD). SPn_{A+C}-m3 tested the interaction between negative probe conditions and cognitive style, that is the modulation of semantic interference effect by cognitive styles. In all three models, participants were treated as a random effect. Table shows information and statistics for each model.

Model	Fixed Factor	Fixed Factor Statistics		Model Statistics			
		F	p	AIC	BIC	r^2_m	r^2_c
SPn-m1	Negative Probe Condition	54.67	< .001	- 152	- 141	.04	.87
SPn-m2	Negative Probe Condition	54.67	< .001	- 154	- 139	.10	.87
	EFT Score	3.05	.08				
SPn-m3	Negative Probe Condition	14.82	< .001	- 152	- 134	.10	.87
	EFT Score	2.95	.09				
	Negative Probe Condition x EFT Score	.06	.79				

Appendix 10 Linear mixed models: Semantic probe, positive trials. SPp-m1 investigates the main effect of the two positive probe conditions (Related, Unrelated), namely a semantic interference effect. SPp-m2 probes the main effect of both positive probe conditions and cognitive style (FI/FD). SPp-m3 tested the interaction between positive probe conditions and cognitive style, that is the modulation of semantic interference effect by cognitive styles. In all three models, participants were treated as a random effect. Table shows information and statistics for each model.

Model	Fixed Factor	Fixed Factor Statistics		Model Statistics			
		F	p	AIC	BIC	r^2_m	r^2_c
SPp-m1	Positive Probe Condition	.69	.40	- 126	- 116	.09	.67
SPp-m2	Positive Probe Condition	.69	.40	- 126	- 113	.19	.67
	EFT Score	1.55	.21				
SPp-m3	Positive Probe Condition	1.97	.16	- 125	- 110	.21	.69
	EFT Score	1.55	.21				
	Positive Probe Condition x EFT Score	1.28	.26				

Appendix 11 Linear mixed models: Global model (GM). This model investigates the nature of individual differences in semantic interference effects during lexical access, considering the individual's performance in the Stroop and semantic probe tasks as well as the EFT score as possible sources of inter-individual variation. In this model, participants were treated as a random effect. Table shows information and statistics for each model.

Model	Fixed Factor	Fixed Factor Statistics		Model Statistics			
		F	p	AIC	BIC	r^2_m	r^2_c
GM	Ordinal Position	53.32	< .001	2832	2894	.30	.70
	Ordinal Position x EFT	4.63	.03				
	Ordinal Position x Stroop Interference	.25	.61				
	Ordinal Position x Semantic Probe Interference	.45	.50				
	Ordinal Position x EFT x Stroop Interference	.21	.64				
	Ordinal Position x EFT x Semantic Probe Interference	.70	.40				
	Ordinal Position x EFT x Stroop Interference x Semantic Probe Interference	1.01	.31				

Appendix 12 Pearson correlations among the tasks and Bonferroni-corrected p-values. Significant correlations are in bold.

		CPNI	Interference Associated	Interference Combined	Interference Associated+Combined	Interference Related
CPNI	Correlation coefficient	1	- .10	.005	- .05	- .06
	p		.48	.97	.70	.66
Interference Associated	Correlation coefficient	- .10	1	**.61**	**.90**	.005
	p	.48		**< .001**	**< .001**	.97
Interference Combined	Correlation coefficient	.005	**.61**	1	**.89**	- .06
	p	.97	**< .001**		**< .001**	.65
Interference Related	Correlation coefficient	- .06	-005	- .06	- .03	1
	p	.66	.97	.65	.82	
Stroop Interference	Correlation coefficient	- .10	.19	.06	.14	.26
	p	.48	.21	.69	.35	.08
EFT	Correlation coefficient	**.46**	.14	.23	.21	- .13
	p	**< .001**	.34	.11	.16	.36

Appendix 13 Stimuli for Continuous Picture Naming. Permitted synonyms in parenthesis

Birds: duck, hen (chicken), ostrich, owl, parrot, pelican, pigeon, robin, rooster.

Clothing items: coat, glove, jacket (blazer), shirt, skirt, sock, sweater (jumper), trousers (chinos), vest.

Bathroom items: comb, perfume, razor, soap, toilet paper, toothbrush, toothpaste, towel, tweezers.

Farm Animals: bull, calf, cow, donkey (mule), goat, horse, lamb, pig, sheep.

Furniture: armchair, chair, chest, chest drawers, cot, sofa, stool, table, wardrobe.

Kitchen appliance: blender, dishwasher, hoover, kettle, microwave, oven, toaster, washing machine, whisks.

Instruments: accordion, drum, flute, guitar, harp, piano, saxophone, trumpet, violin.

Landscape: beach, desert, iceberg, lake, mountain, river, sea, volcano, waterfall.

Reptiles: chameleon, cobra, crocodile, frog, iguana, lizard, python, toad, turtle.

Sweet Foods: brownie, cake, chocolate, cookie, croissant, doughnut, ice-cream, marshmallow, muffin.

Tools: axe, chisel, clamp, drill, hammer, pliers, screwdriver, shears, shovel.

Transports: bicycle, bus, caravan, helicopter, motorbike, plane, tractor, train, van.

Appendix 14 Stimuli for Continuous Picture Naming (list A and list B). Permitted synonyms in parenthesis

List A
Birds: goose, robin, hen (chicken), pigeon, parrot.
Body parts: tongue, finger, eye, arm, leg.
Buildings: shed, barn, lighthouse, church, factory.
Clothing items: jacket (blazer), socks, sweater (jumper), vest, shirt.
Electrical items: headphones, radio, camera, monitor (screen), printer.
Farm animals: horse, bull, lamb, calf, donkey (mule).
Flowers: poppy, daffodil, tulip, daisy, dandelion.
Fruits: kiwi, apple, lemon, strawberry, pear.
Furniture: chest, sofa, armchair, stool (chair), bookcase.
Insects: bee, butterfly, spider, grasshopper (cricket), centipede.
Kitchen appliances: blender, whisks, washing machine, oven, microwave.
Kitchen utensils: fork, colander, cup, knife, frying pan.
Instruments: drum, guitar, flute, harp, saxophone.
Landscapes: cliffs, river, mountain, lake, sea.
Reptiles: crocodile, toad, turtle, python, iguana.
Savory food: pizza, chicken, cracker, toast, steak.
Sea creatures: crab, starfish, eel, squid, lobster.
Stationary: pen, ruler, folder, paperclip, eraser.
Sweet food: ice cream, marshmallow, brownie, cake.
Bathroom items: soap, perfume, bud, toothbrush, toilet paper.
Tools: axe, chisel, shears, pliers, drill.
Vegetables: carrot, onion, tomato, lettuce, cauliflower.
Transport: tram, bicycle, plane, tractor, caravan.
Safari animals: hippopotamus, camel, kangaroo, giraffe, cheetah.
List B
Birds: rooster (cockerel), duck, pelican, owl, ostrich.
Body parts: nail, ear, mouth (lips), foot, nose.
Buildings: cathedral, windmill, skyscraper, tower, castle.
Clothing items: trousers (chinos), skirt, glove, bathrobe, coat.
Electrical items: laptop, telephone, speaker, mouse, keyboard.
Farm animals: sheep, cow, pig, goat, ox.
Flowers: cactus, sunflower, lavender, rose, lily.
Fruits: pomegranate, orange, cherries, grapes, melon.
Furniture: chair, cot, chest, wardrobe, table.
Insects: worm, beetle, ant, moth, ladybird.
Kitchen appliances: dishwasher, food processor, toaster, kettle, hoover.
Kitchen utensils: spoon, spatula, glass, bowl, pot.
Instruments: piano, trumpet, violin, clarinet, accordion.
Landscape: beach, waterfall, iceberg, desert, volcano.
Reptiles: frog, cobra, lizard, newt, chameleon.
Savory food: beans, ham, cheese, bacon, hamburger.
Sea creatures: prawn (shrimp), clam, octopus, oyster, jellyfish.
Stationary: pencil, pin, compass, stapler, sharpener.

Sweet food: cookie, doughnut, croissant, muffin, chocolate cheesecake.
Bathroom items: towel, razor, comb, toothpaste, tweezers.
Tools: shovel, mallet, screwdriver, clamp, hammer.
Vegetables: asparagus, potato, pepper, cucumber, celery.
Transports: train, bus, van, helicopter, motorbike.
Safari animals: elephant, tiger, lion, rhino, zebra.

Appendix 15 Stimulus statistics for two lists of continuous picture naming task; frequency from CELEX Database (Baayen et al., 1995). AoA: Age of acquisition (Kuperman et al., 2012).

	Position										Total	
	1		2		3		4		5		M	SD
	M	SD	M	SD	M	SD	M	SD	M	SD		
List A												
Frequency	15	20	15	20	19	29	21	38	18	36	18	29
AoA	6	2	6	2	6	2	6	2	6	2	6	2
Length	6	2	6	2	6	3	6	2	6	2	6	2
List B												
Frequency	23	29	20	30	20	40	28	26	19	46	22	34
AoA	6	2	5	2	6	2	6	2	7	2	6	2
Length	6	2	6	3	6	2	6	2	6	2	6	2

Appendix 16 Stimuli for Continuous Picture Naming

Stationary: paintbrush (pennello), pen (penna), pencil (matita), sharpener (temperamatite), ruler (righello)
Zoo Animals: elephant (elefante), giraffe (giraffa), gorilla (gorilla), monkey (scimmia), panda (panda)
Body Parts: arm (braccio), nose (naso), ear (orecchio), foot (piede), leg (gamba)
House Parts: chimney (camino), floor (pavimento), roof (tetto), stairs (scale), window (finestra)
Farm Animals: cow (mucca), donkey (asino), goat (capra), pig (maiale), sheep (pecora)
Clothes: trousers (pantaloni), dress (vestito), shirt (camicia), skirt (gonna), sweater (maglione)
Insects: ant (formica), butterfly (farfalla), fly (mosca), mosquito (zanzara), spider (ragno)
Furniture: bed (letto), chair (sedia), desk (scrivania), sofa (divano), table (tavola)
Garden Tools: hose (pompa), lawnmower (tagliaerba), rake (rastrello), watering can (annaffiatoio), wheelbarrow (carriola)
Equipment: hinge (cardine), hook (uncino), nail (chiodo), nut (dado), screw (vite)
Kitchen: cloth (panno), funnel (imbuto), kitchen (cucina), rolling pin (mattarello), scale (bilancia)
White goods: mixer (frullatore), radio (radio), refrigerator (frigorifero), toaster (tostapane), washing machine (lavatrice)
Nature: forest (foresta), desert (deserto), mountain (montagna), volcano (vulcano), waterfall (cascata)
Fruits: banana (banana), grapes (uva), pear (pera), pineapple (ananas), strawberry (fragola)
Musical Instruments: drum (tamburo), guitar (chitarra), piano (pianoforte), trumpet (tromba), violin (violino)

Plants: cactus (cactus), flower (fiore), leaf (foglia), palm tree (palma), tree (albero)
Buildings: castle (castello), church (chiesa), lighthouse (faro), teepee (tenda), windmill (mulino)
Professions: dentist (dentista), doctor (dottore), sailor (marinaio), soldier (soldato), waiter (cameriere)
Weather: cloud (nuvola), lightning (lampo), moon (luna), rainbow (arcobaleno), sun (sole)
Dishes: bowl (ciotola), fork (forchetta), knife (coltello), plate (piatto), spoon (cucchiaio)
Tools: drill (trapano), hammer (martello), pliers (pinze), saw (sega), screwdriver (giravite)
Birds: eagle (aquila), owl (gufo), parrot (pappagallo), peacock (pavone), swan (cigno)
Toys: balloon (palloncino), doll (bambola), puzzle (puzzle), spinning top (trottola), yoyo (yo yo).
Vehicles: airplane (aeroplano), boat (barca), car (auto), motorbike (motocicletta), train (treno)

Appendix 17 Stimuli for Cyclic Blocking Naming

Fruits: Banana (Banana), Coconut (Cocco), Grape (Uva), Lemon (Limone), Orange (Arancia), Strawberry (Fragola)
Insects: Bee (Ape), Butterfly (Farfalla), Fly (Mosca), Grasshopper (Cavalletta), Mosquito (Zanzara), Spider (Ragno)
Tools: Drill (Trapano), Hammer (Martello), Hoe (Zappa), Pliers (Pinze), Saw (Sega), Scissors (Forbici)
Animals: Dog (Cane), Fish (Pesce), Lion (Leone), Panda (Panda), Rabbit (Coniglio), Zebra (Zebra)
Vehicles: Ambulance (Ambulanza), Canoe (Canoa), Car (Auto), Bicycle (Bicicletta), Gondola (Gondola), Helicopter (Elicottero), Train (Treno)
Body Parts: Arm (Braccio), Eye (Occhio), Leg (Gamba), Mouth (Labbra), Nose (Naso), Wrist (Polso)
Food: Cake (Torta), Ice-cream (Gelato), Pizza (Pizza), Popcorn (Popcorn), Steak (Bistecca), Turkey (Tacchino)
White Goods: Radio (Radio), Refrigerator (Frigorifero), Telephone (Telefono), Vacuum cleaner (Aspirapolvere), Washing machine (Lavatrice)
Clothes: Dress (Vestito), Glove (Guanto), Hat (Cappello), Necktie (Cravatta), Sock (Calzino), Trousers (Pantaloni)
Birds: Peacock (Pavone), Penguin (Pinguino), Rooster (Gallo), Swan (Cigno), Swallow (Rondine)
Furniture: Bed (Letto), Crib (Culla), Desk (Scrivania), Sink (Lavandino), Sofa (Divano), Table (Tavolo)
Professions: Chef (Cuoco), Fireman (Pompiere), Nurse (Infermiera), Painter (Pittore), Policeman (Poliziotto), Teacher (Insegnante)