Differential impact of disfiguring facial features on overt and covert attention

Luc Boutsen

Nathan A. Pearson

Martin Jüttner

Aston University, Birmingham, UK

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Correspondence:

Luc Boutsen

Department of Psychology

Aston University

Birmingham B4 7ET

United Kingdom

l.boutsen@aston.ac.uk

Abstract

Observers can form negative impressions about faces that contain disfiguring features (e.g., scars). Previous research suggests that this might be due to the ability of disfiguring features to capture attention — as evidenced by contrasting observers' responses to faces with or without disfiguring features. This, however, confounds the effects of salience and perceptual interpretation, i.e. whether the feature is seen as integral to the face, or separate from it. Furthermore, it remains unclear to what extent disfiguring features influence *covert* as well as *overt* attention. We addressed these issues by studying attentional effects by photographs of unfamiliar faces containing a unilateral disfigurement (a skin discoloration) or a visually similar control feature that was partly occluding the face. Disfiguring and occluding features were first matched for salience (Experiment 1). Experiments 2 and 3 assessed the effect of these features on covert attention in two cueing tasks involving discrimination of a (validly or invalidly cued) target in the presence of, respectively, a peripheral or central distractor face. In both conditions, disfigured and occluded faces did not differ significantly in their impact on response-time costs following invalid cues. In Experiment 4 we compared overt attention to these faces by analysing patterns of eye fixations during an attractiveness rating task. Critically, faces with disfiguring features attracted more fixations on the eyes and incurred a higher number of recurrent fixations compared to faces with salience-matched occluding features. Together, these results suggest a differential impact of disfiguring facial features on overt and covert attention, which is mediated both by the visual salience of such features and by their perceptual interpretation.

Differential impact of disfiguring facial features on overt and covert attention

1. Introduction

The human face is a critical stimulus during social interactions. It offers observers a variety of cues to identity, gender, emotion and intention, but also to health or biological fitness. Indeed, visual cues from facial appearance can affect our perception of, and behaviour towards others (Zebrowitz & Montepare, 2008). Conversely, a face can signal reduced fitness or even disease through the presence of facially disfiguring features, whose perception can affect observers' cognitions about, and behaviour towards, that person. In this study we investigate the effect of facially disfiguring features on attention to faces. In the following, we will first review the role of facially disfiguring features on behaviour and then discuss their relation to attentional capture by facial stimuli.

Facially disfiguring features (FDFs) such as birth marks, spots, surgical or accidental scars, or certain craniofacial or dermatological disorders (e.g., cleft lip and palate, port wine stains, or vitiligo) can alter facial appearance and influence how the person with the disfigurement is perceived by others. Indeed, FDFs determine not only how the person bearing the feature perceives themselves (Rumsey, 2002) but also how they are perceived and treated by others (Rumsey, Bull & Gahagan, 1982; Turner, Rumsey, & Sandy, 1998; Shanmugarajah, Gaind, Clarke, & Butler, 2012). For example, Blascovich, Berry Mendes, Hunter, Lickel and Kowai-Bell (2001) found that participants who interacted with a confederate during a word finding task generated fewer words when the confederate carried a birth mark than when s/he did not. Interestingly, participants who interacted with the birth mark bearing confederate also displayed cardiovascular reactivity consistent with a learned response towards or emotionally negative or threatening stimuli (Öhman & Mineka, 2001). The relationship between a FDFs and threat is further supported by evidence that observers perceive, and respond to, FDFs as disease-signalling. For instance, viewing images of real facial disfigurements can elicit feelings of disgust that correlate with the degree of the disfigurement (Shanmugarajah, Gaind, Clarke, & Butler, 2012). Such responses are not limited to explicit measures, but extend to implicit measures as well. For instance, Ryan, Oaten, Stevenson and Case (2012) asked participants to handle objects in the same manner as shown by an actor in a video. When the actor simulated disease symptoms (e.g., influenza) or displayed a (simulated) facially disfiguring feature, participants avoided close facial – oral – contact with the objects and were more likely to display facial disgust. Similarly, Ackerman et al (2009) found that observers who had been primed to think about disease were slower to disengage attention in a subsequent dot-probe task when being presented with disfigured faces relative to normal ones, or in comparison to participants who had been primed in a neutral control condition. Together, these results suggest that FDFs can elicit, explicitly and implicitly, responses from observers similar to those evoked by threat- or disease-signalling stimuli. They also indicate that these effects might be mediated by a particular attentional control that FDFs exert in the presence of a meaningful semantic context. Whether FDFs can capture attention on their own, i.e. in the absence of such a context, is less clear.

Given the speed and ease with which observers form first impressions from faces (Willis & Todorow, 2006) it is conceivable that the presence of a disfiguring feature alters the way in which observers attend to a face. Eye tracking studies suggest that observers scan faces containing a disfiguring feature differently compared to faces without such features. Ishii, Carey, Byrne, Zee and Ishii (2009) measured fixation patterns of participants looking at photographs of patients with and without peripheral facial deformities. Observers' gaze direction when viewing faces with deformities was consistently deflected away from the central eye-nose-mouth region of the face and towards the periphery which contained the disfiguring feature. A similar eye gaze bias towards facial disfigurements was reported by Meyer-Marcotty, Gerdes, Reuther, Stellzig-Eisenhauer, and Alpers (2010) who asked observers to view photographs of unfamiliar faces of patients with cleft lip and palate. Such oculomotor biases can also be accompanied by biases in memory and cognition in relation to the faces, such as memory for what the person bearing the FDF said (Madera and Heble, 2012).

While the above studies suggest that FDFs affect attention, two questions remain unaddressed:

1. Do facial disfigurements capture covert attention? First, it is unclear whether FDFs affect overt and covert attention differently. In the aforementioned studies by Ishii et al., Meyer-Marcotty et al. and Madera and Hebel observers were free to make eye movements towards the face stimuli, i.e. to redirect their overt visual attention. The fact that such overt attentional shifts may be driven by preceding shifts of covert attention, i.e. attentional shifts with the eyes still being stationary (see e.g., Carrasco, 2011, for a review), prompts the question whether similar to the observed deflection of gaze towards FDFs there is also a deflection of covert attention. Alternatively, such gaze deflections – typically operationalized on the basis of the durations of fixations on a specified target region cumulated across the inspection period - may reflect an increased level of sustained overt attention towards FDFs only.

2. Are effects of facial disfigurements on attention due to visual salience alone? Facial disfigurements by their very nature are visually conspicuous features, i.e., they may attract attention through their visual salience. However, such disfigurements may also capture attention by the fact that they are *facial* features. This raises the question whether the attentional effects of FDFs are modulated by their perceptual interpretation, i.e. whether they are seen as an intrinsic part of the face (e.g., ”a spot on a face”) rather than as an extrinsic feature, i.e. a feature accidentally coinciding with the face but physically separate from it (e.g., “a spot on the depiction of a face”). Previous studies considering the effect of FDFs on attention (Ishii et al., 2009; Meyer-Marcotty et al., 2010; Madera and Hebel, 2012) contrasted observers' responses to static photographs of faces with or without disfiguring features, thus confounding the relative effects of salience and perceptual interpretation. Similarly, studies assessing the semantics of FDFs, i.e. their ability to signal disease or the threat of infection (Ackerman et al., 2009; Blascovich et al., 2001; Ryan et al., 2012), were based on the implicit assumption that FDFs are seen as part of the face, without accounting for the impact this particular perceptual interpretation may have on any subsequent semantic evaluation.

To overcome the above limitations regarding the attentional control FDFs exert and the perceptual interpretation they induce, the present study employed three types of face stimuli: without any added features (henceforth labelled "normal"), with a "disfiguring" feature, and with a "control" feature. As described in more detail in the following section disfiguring and control features were similar in colour and texture but differed in terms of their perceptual interpretation: While disfiguring features were morphed into the face and its outline, control features where placed as rectangular patches over the face such they that did not follow the face outline but rather occluded it. Furthermore, in a calibration study (Experiment 1) a set of faces was derived for which disfiguring and control features were matched in saliency. Using these face stimuli we evaluated effects on covert (Experiments 2 and 3) and overt attention (Experiment 4).

Experiments 2 and 3 employed a variation on the spatial cueing paradigm (Posner, 1980; Posner, Snyder & Davidson, 1980), in which a predictive central cue directing attention to the left or right visual field was followed by a target stimulus and a distractor face. Participants had to indicate the orientation of the target. Continuous eye tracking enabled to ascertain that observers attended covertly to the cued location.

In Experiment 2, the distractor face (if present) was located opposite to the target. If salient facial features influence covert attention then their presence might increase the interference by distractor faces, especially when attention is directed to the distractor (on invalidly cued trials). In Experiment 3, the distractor face was presented centrally while the target appeared to its left or right side. This allowed to assess the impact of spatial proximity of the target relative and to the location of a salient facial feature on the (dis)engagement of covert attention. In Experiment 4 we measured overt attention to the same faces as in Experiments 2 and 3. Observers viewed peripheral faces to which they made eye movements in anticipation of an attractiveness rating. If salient features capture attention we would expect these to influence the distribution of fixations on the face, with more fixations towards the feature and fewer fixations on the eyes — the preferred fixation region during the spontaneous exploration of normal faces (Barton, Radcliffe, Cherkasova, Edelman, & Intriligator, 2006; Boutet, Lemieux, Goulet, & Collin, 2017).

2. Experiment 1 (stimulus calibration)

Our study involved images of unfamiliar faces which could contain a unilateral salient feature (Figure 1): a simulated realistic looking skin discoloration on the face, or a feature that partly occluded the face. Our aim was to assess whether attention to faces was affected by the perceptual interpretation of the added feature. More specifically, we used features to the faces (Figure 1B and 1C) that possessed similar local visual properties (in terms of contrast, luminance, and texture) but differed regarding their global visual properties such as shape and occlusion, hence inducing a different perceptual interpretation. This construction principle resulted in two types of features: a disfiguring feature (Figure 1B) that created the impression of a so-called ‘port wine stain’, morphed to follow the contour of the cheek and jawline and therefore being perceived as an integral part of the face surface; and an occluding feature (Figure 1C) that could be interpreted as an addition to the image rather than to the face (i.e., a rectangle that partially occludes an otherwise normal face).

These two types of facial manipulations were applied to all faces in our face database. Given that the relative conspicuity of a particular manipulation depends on the spatial context of the individual face, Experiment 1 was conducted to identify a subset of faces for which disfigured and occluded features were matched in terms of their visual salience. For this purpose we adopted a standard procedure used in the object recognition literature to equate featural object manipulations (see, e.g., Davidoff & Roberson, 2002; Biederman & Bar, 1999). It involved a visual matching task, in which observers judged whether two simultaneously presented face images were the same or different. By pairing 'normal' versions of a given face identity with either the 'disfigured' or 'occluded' version thereof, the response time for correct 'different' responses served as an empirical measure of visual salience of the respective face manipulation for that particular face identity. Based on this measure we derived a subset of faces from our face database, for which 'disfigured' and 'occluded' versions of a face were matched in terms of their salience relative to the 'normal' version as their common reference.

2.1. Method

2.1.1. Participants

Twenty-two right-handed students from Aston University (15 women and 7 men, mean age 20.2 years [range: 18-29]) and of Asian (7), Black (1), White (13) or Mixed (1) ethnicity took part in exchange for course credits or a £5 payment. In this and the following experiments, all reported normal or corrected vision, and all gave written informed consent prior to participating, and all were unfamiliar with the face stimuli.

2.1.2. Stimuli and materials

The face stimuli were constructed from 80 Caucasian face identities (40 males, 40 females) from three face databases: The Glasgow Unfamiliar Face Database (Burton, White, & McNeill, 2010), the NimStim face database (Tottenham et al., 2009) and a database available from http://pics.stir.ac.uk/zips/utrecht.zip. All faces had a neutral expression shown from a frontal viewpoint, and were presented in colour. All images were cropped to the same width (400 pixels, 8.72º) while maintaining aspect ratio. Backgrounds were removed and differences in colour balance and brightness were manually adjusted to reduce low-level image variability. The resulting images had similar luminance values prior to manipulation. All images were presented on a white background.

Each of the 80 faces were edited to create 4 unilateral facial feature conditions: left-half disfigured, right-half disfigured, left-half occluded, and right-half occluded (note that the location of the feature on the face is labelled relative to the observer's viewpoint; thus, *left-half* features appear to the left of the observer). These four conditions were used in addition to two (left-right mirror-reversed) versions of the *normal* condition, i.e. without added features (Figure 1A). This resulted in a stimulus set of 480 images.

Disfigured face conditions (Figure 1B) were created by digitally replacing the skin texture on the left or right side of the face with that of image texture derived from publicly available example images of patients depicting actual facial port-wine stains (*nevus flammeus*, a discoloration of the skin caused by congenital malformation of superficial blood vessels). The 'port-wine stain' texture covered ~38% of the central area (footnote 1) of the face, and included parts of the forehead, the cheek and the chin. This texture was blended in with the original skin tone so as to create the impression of a skin disfigurement. The choice of disfigurement was guided by the aim of creating the impression of a disease-signalling disfiguring feature, but we did not attempt a medically accurate simulation of a specific disfigurement.

In the occluded face condition, a rectangular patch (100 × 170 pixels or 1.78˚ × 3.04˚, covering ~15% of the central area of the face (footnote 2)) of the same image texture used to create disfiguring features was positioned partially over the left or right cheek (Figure 1C).

We used the same image texture to increase low-level visual similarity between the occluding and disfiguring features. To further emphasize its perceptual interpretation as a feature separate from the face, we added to the patch a 2-pixel wide black border to delineate it from the surrounding face image. The patch partly covered the background, creating the impression of occlusion. The disfigured faces were designed to create the impression of containing a salient 'non-accidental' or viewpoint-invariant feature (intrinsic to the face; Biederman, 1987), while the occluded faces would give the impression of an accidental feature not intrinsic to the face.

2.1.3. Design

A visual matching task was employed, in which observers judged whether two simultaneously presented face images were the same or different. On 'same' trials, a face with a normal (N), disfiguring (D) or occluding (O) feature was presented twice, side by side (i.e., N-N, D-D, O-O) with the restriction that the feature in both images was always on the same side (left or right). Thus, on 'same' trials the images were visually identical. On 'different' trials, each of six possible pairings of normal, disfigured and occluded faces (i.e., N-D, D-N, N-O, O-N, D-O, O-D) in each feature location (left- or right-sided; thus, 12 combinations in total) was presented. When both faces in a pair had an added feature (e.g., a disfiguring feature or an occluding feature), these features appeared always on the same side relative to the face (e.g. a face with a left-sided feature was never paired with a face with a right-sided feature). Each participant was presented with 480 experimental trials during 24 blocks of 20 trials each, with self-paced breaks in between blocks. There were 240 'same' trials, consisting of 40 trials of each of 4 conditions by combining facial feature type (disfiguring, occluding) and feature location (left-sided or right-sided), plus 80 trials consisting of face pairs with no added feature ('normal' face pairs). In addition there were

240 ‘different’ trials, consisting of 20 trials of each of 12 combinations of facial feature type and 2 feature location as described above.

2.1.4. Procedure

Stimuli were presented on a 22-inch Iiyama ProLite LCD monitor (1920 × 1080 pixels, 60 Hz retrace rate). The experiment was controlled by E-Prime 2.0 Professional programs using unique trial lists for each participant. Each image pair consisted of two faces of the same identity drawn from the same database of 80 face identities. Each face identity was presented on average 3 times (*SD* = 0.26) to the same participant in an experiment on ‘same’, and 3 times (*SD* = 0.26) on ‘different’ trials. All paired face conditions and face identities were presented in a unique random order to each participant.

Each participant was tested individually in a 35-min session. Each session started with 10 practice trials with feedback on incorrect trials. On each trial a fixation cross was presented for 1 s followed by the face pair until a response was made; a blank screen of 1.5 s following a response concluded the trial before the next trial started. Participants pressed *z* and *m* keys on a standard keyboard to make, respectively, ‘same’ or ‘different’ responses; this mapping was reversed for half of the participants. Participants were instructed to maintain eye gaze at the centre of the screen throughout each trial and were asked to respond as soon as possible while minimizing errors.

2.2. Results

Sensitivity. To describe discrimination performance between the three face types, we computed signal sensitivity for same-different paired comparisons. From the number of ‘same’ and ‘different’ responses to *same* and *different* face pairs for each of normal vs. disfigured, normal vs. occluded and disfigured vs. occluded pairs, we estimated for every participant sensitivity δ (delta) and a decision criterion τ (tau) (Christensen & Brockhoff, 2009). Because δ is the adjusted discrimination index d' for same-different discrimination tasks (Creelman & Macmillan, 1979; Kaplan, Macmillan & Creelman, 1978; Macmillan & Creelman, 1991, Eq. 9.3), we will denote it henceforth as *d'*. All values of *d'* and τ were calculated from the number of correct and incorrect responses (per participant) on same and different trials for each combination of face type (e.g., normal vs. disfigured), using the *samediff* function in the *sensR* package in *R* (Christensen & Brockhoff, 2008). Table 1 shows the sensitivity and criterion indices (averaged across participants) per condition, alongside the average of upper and lower boundaries of the 95% confidence intervals. Sensitivity was largest to the difference between normal and occluded faces, and lowest between normal and disfigured faces. Three one-tailed paired *t*-tests with $\alpha = .0167$ (corrected for multiple comparisons) revealed that sensitivity to the difference between normal and occluded faces was both larger than that between normal and disfigured ($t(21) = -5.85$, $p < .001$), and between disfigured and occluded faces ($t(21) = -4.35$, $p < .001$); the difference in sensitivity between normal-disfigured and disfigured-occluded pairs was not reliable ($t(21) = -1.97$, $p = .030$).

Response times. Average RTs per condition on same and different trials are presented in Table 2. *Same* responses were fastest to pairs of normal faces, and slowest for pairs of disfigured faces. *Different* responses were fastest to face pairs consisting of a normal and an occluded face. To evaluate the effect of condition on RTs we performed linear mixed effects analyses (footnote 3), starting from a model including all random (by-participants and by-items) and fixed effects and all their interactions; we report the first model that converged. First, an analysis of log-transformed RTs with trial type and face pair type and their interactions as fixed effects, and participant and item (face identity) as random factors showed a reliable interaction between trial type (same vs. different) and face type ($B = .051$, $SE = .006$, $t = 7.78$), but no main effects of trial type ($t = -1.36$) or face pair type ($t = 1.35$). Two further analyses of the effect of face pair type with trial type as a fixed factor (and participants, item, and by-participant and by-item slopes of trial type as random effects) showed a main effect of face pair type both on same (B = .0297, SE = .0071, t = 4.19) and on different trials (B = -.0217, SE = .0074, t = -2.8).

Determining response-matched stimuli. Performance in this visual matching task was used to identify a subset of face stimuli for which the two face manipulations (disfigured vs. occluded) were matched for salience. In principle, either response time, i.e. the speed of discrimination between the disfigured/occluded and the normal (non-manipulated) image version of the same face identity, or the respective accuracy of such a response could serve as performance indicator in that context. However, as our stimulus pairs were highly distinguishable and discrimination accuracy typically yielded values of ~90% or above (Table 2) we decided to base our saliency measure on response time in order to avoid distortions by ceiling effects. More specifically, salience was operationalized in terms of the time required by the observer to produce a *different* response to face pairs consisting of either a disfigured and normal image version of a particular face identity (N-D and D-N face pairs, henceforth generically referred to as DN pairs), or an occluded and normal version (N-O and O-N face pairs, henceforth ON pairs). To construct a stimulus subset with matched salience of the two conditions, for each of the 80 face identities in our face database the mean response time difference $RT_{DN\text{-}ON}$ (averaged across observers, feature location and viewing condition) between DN and ON face pairs was computed. Based on the distribution of these differences ranging from -100 ms to 500 ms we defined a subset of faces identities with $RT_{DN\text{-}ON} < RT_C$. The cut-off point RT_C was determined in such a way that the median of all $RT_{DN\text{-}ON}$ values within the subset approached 0. Thus our construction principle guaranteed a subset of face identities matched in salience, being maximally inclusive (in terms of retaining stimuli from the original stimulus set) and showing a minimal variance regarding $RT_{DN\text{-}ON}$. The resulting matched-salience subset retained 35 of the 80 face identities in the original stimulus set. For this subset set response time differences between DN and ON face pairs were not reliable (two-tailed paired $t < 1$; Table 3).

2.3. Discussion

Observers were better at discriminating faces containing occluding than disfiguring facial features from faces that did not contain these features. Importantly, however, the salience values for disfiguring and occluding features, as reflected in the discrimination performance in our matching task, varied depending on the visual context provided by the individual faces in our stimulus database, resulting in a considerable overlap between their respective distributions. This allowed us to identify a subset of faces for which disfigured and occluded features were effectively matched in terms of salience.

While the subsequent Experiments 2 to 4 were conducted using the original, full set of face stimuli, we will report in this article mainly the data from the subset of salience-matched faces (unless otherwise indicated). We note that the main conclusions derived from this subset also hold for the full stimulus set as additional analyses demonstrated. These results are presented as supplementary material and will be referred to as required.

3. Experiment 2

Experiment 2 assessed the impact of a peripherally presented, unfamiliar face containing an unilateral salient feature on covert attention. We adapted Sui and Liu’s (2009) variant of the classic spatial cueing paradigm (Posner, 1980; Posner, Snyder & Davidson, 1980). Here a predictive central cue directing attention to the left or right visual field is followed by a target stimulus and a distractor face that are presented at mirror symmetric locations in the left and right hemifield (Figure 2). The participant has to indicate the orientation of the target.

Discrimination of the target at validly cued locations tends to be faster and more accurate than at invalidly cued locations — a cueing benefit (Fox et al., 2001; Posner, 1980). This is because on invalid trials covert attention needs to disengage from the invalidly cued location and (re-)engage at the cued location. The presence of a distractor face might reduce the cueing benefit by attracting attention away from the cue. The effectiveness of attentional capture by the distractor face might be further enhanced by the presence of salient feature on that face. We predicted that a disfiguring facial feature would lead to a stronger reduction of the observed cueing benefit than an equally salient control feature.

3.1. Method

3.1.1. Participants

Thirty-eight students and staff from Aston University took part in exchange for course credits or a £5 payment. There were 27 females and 11 males aged 18-54 years (M = 23.4, SD = 7.5), from various ethnic backgrounds (18 White, 8 Black, 8 Asian and 4 South-East Asian) and there were 6 lefthanders.

3.1.2. Design

A within-subjects design was used with cue validity, target location and distractor type as independent variables. The experiment consisted of 320 trials of which 256 with valid cues (80%) and 64 with invalid cues (20%). On valid and invalid trials, equal numbers of each of six distractor conditions – a baseline condition with no distractor and 5 types of face distractors – and one of two target stimuli were presented. On 75% of trials, the target was presented with a distractor face, and on the remaining 25% trials it appeared without any distractor. A distractor face (when present) appeared in one of the following conditions with equal probability: as a *normal* face (without any added feature), a *disfigured* face with a left- or right-side disfiguring feature, or an *occluded* face with a left- or right-side occluding feature. Each distractor was presented to each participant in randomly allocated cue and distractor location conditions. That is, each participant was exposed on trials containing a distractor face with each face identity in three of the distractor conditions. Target and distractor (left-right) locations were counterbalanced, as was cue direction.

3.1.3. Apparatus and stimuli

The experiment was run on a PC using E-Prime 2.0 Professional. Stimuli were presented on a 22-inch Iiyama ProLite LCD monitor (1920 × 1080 pixels, 60 Hz retrace rate). All stimuli were presented on a uniform grey background. Drawn elements were presented in white and the faces were presented in colour (8 bits per colour channel). During each trial, the right-eye position of each observer was monitored at 1 kHz using a desktop-mount Eyelink 1000 eye tracker (SR Research) with a chin/forehead rest positioned at a viewing distance of 80 cm.

Cue and target stimuli. Cues and target stimuli were designed after Sui and Liu (2009). The target and, if present, the distractor face appeared within 2 square boxes (7 pixels thick border; width: 150 pixels or 13.5˚), presented alongside the central cue and visible throughout the entire trial. The edge nearest to the centre of the screen was 3.17˚, and the outer edge was 16.66˚. (footnote 4) The cue was a < or > sign of 1.5º, instructing for attention to left or right box, respectively. There were two target patterns, consisting of either an upright or an inverted T shape, surrounded by eight + symbols; each element fitted within a 100 pixels (1.78º) wide square.

Face distractor stimuli. The set of distractor faces was composed of 240 images, in which half of the identities of each face gender were randomly assigned to the left-half feature conditions, and the other half to the right-half feature conditions.

3.1.4. Procedure

Each participant was tested individually under normal lighting in a 40-min. session. Twenty practice trials with feedback were followed by 320 trials without feedback, in 16 blocks of 20 trials. Each trial (Figure 2) started with a fixation cross for 500 ms alongside 2 boxes (in which the target and distractor face were displayed) which were visible throughout the trial. At its offset the cue appeared for 200 ms, directing attention to either the left or the right box. After an interval of 75 ms during which the fixation cross reappeared, a target pattern and (if present) a distractor face were presented in the left and right boxes for 200 ms with the target appearing on 80% of the trials in the box indicated by the cue, and in the opposite box on the remaining 20%. The target display was replaced by the fixation cross until response and was followed by a 1.5 s inter-trial interval.

Each participant was instructed to maintain eye gaze at the centre of the screen (the location of the cue) throughout the entire trial while attending to the box indicated by the cue in anticipation of the target pattern. Their task was to determine whether the T within the target pattern was upright or upside down by making bimanual responses using, respectively, the *z* or *m* keys on a keyboard. This mapping was reversed for half of the participants.

Prior to the experiment each participant was shown one example each of a normal, disfigured or occluded face, and the “features” were pointed out; no explanation was provided as to their interpretation. Participants were instructed to ignore the face and to respond fast without sacrificing accuracy. They were informed that the cue was predictive to encourage covert orienting to the cued direction. Eye position was measured from cue onset until response to ascertain central eye gaze. Prior to each session, each participant was seated (with their head on a chin rest) in front of the eye tracking camera to obtain a valid pupil and corneal reflection image. During a 9-point calibration, each participant focused on a black dot of 6 pixels) presented randomly in a 3 × 3 array evenly spread across the display area. Calibration was successful when all 9 locations had a deviation of less than 1º, and if unsuccessful it was repeated. A drift correction was applied every 20 trials, during which the participant fixated a central red fixation cross. During the calibration and during each trial each participant was asked to move and eye-blink as little as possible; this was monitored by the experimenter, who also encouraged the participant to relax as much as needed during breaks between blocks.

3.2. Results

Response times (RTs, in ms) and accuracy were measured as a function of cue and distractor type, and the cueing cost was determined by subtracting correct RTs on valid trials from invalid trials. To ensure that results reflected performance under covert attention we determined for every participant the proportion of time during which gaze was maintained within a rectangular area of 169 × 220 pixels (3.01˚ × 3.93˚) centred on the screen (*central dwell percentage*), during a time window from the onset of the cue until the offset of the target stimulus. (footnote 5) Trials in which the central dwell percentage was lower than 90%, and trials in which correct RTs were faster than 200 ms or slower than 4 s were excluded from any analysis. This led to rejection of 5.7% of trials. Using these criteria, each participant had at least 80% of their responses (M = 94.2%, SD = 5.8%) retained for analysis. RTs were analysed as a function of cue validity and distractor type (footnote 6); only correct RTs not exceeding 3 SDs of each participant's average correct RT were retained (88.19% of the data).

Table 3 shows reaction times and accuracy alongside the cueing costs (on RT) and the 95% confidence intervals of the interaction between cue validity and distractor type (adjusted for repeated measures designs; Hollands & Jarmasz, 2010). Responses were on average 20.9 ms slower following invalid than valid cues. When a distractor face was present this cueing cost appeared to vary between the distractor type (from 6 to 19.5 ms), but these effects of the cue were accompanied by large confidence intervals across all distractor conditions, suggesting no effect of distractor type.

We evaluated the above findings using a linear mixed effects (LME) model with by-subjects and by-item random effects (Baayen, Davidson, & Bates, 2008) for the subset of salience-matched distractor faces. Initial models included a maximum random effects structure (Barr, Levy, Scheepers, & Tily, 2013) with random intercepts for 38 participants and the subset of 35 salience-matched face identities, and random slopes for cue validity and distractor type for participants and items. The final model included three fixed factors (cue validity, facial feature type, and facial feature location), all 2-way interactions between fixed factors, all 3-way interactions between fixed factors, a random by-participants effect, intercepts of all main effects by participants, and slopes of all 2-way and 3-way interactions by participants. We report *t* statistics on the fixed effects and compared them to the two-tailed 5% error criterion for significance of $|t| \geq 1.96$ (Hohenstein, Matuschek & Kliegl, 2017).

The LME model of log-transformed RTs to salience-matched faces showed that the cueing benefit of 20.9 ms was not statistically reliable (B = -.0704, SE = .0589, t = -1.19. In addition, there was no effect of the facial feature type (B = -.0035, SE = .0114, t = -0.31) or feature location (B = -.0002, SE = .0073, t = -0.04) and there were no reliable 2-way or 3-way interactions (all $|t| < .75$).

The lack of a statistically reliable cue validity effect even across stimulus conditions is somewhat surprising. Because the above analysis was performed on data from the subset of salience-matched stimuli we also evaluated cue validity effects for the full set of face stimuli (i.e., including those which were not matched for salience); these are reported in Table S1 (Supplementary Material). This time we observed cueing costs for all conditions (between 14 and ~42 ms). Two LME models of log-transformed RTs, one for baseline and distractor faces, and one for feature-bearing distractor faces only, showed a reliable effect of cue validity (Table S2, Supplementary Material). However, this analysis again yielded no significant effects of the presence or the type of facial features, nor their location within the face.

3.3. Discussion

Experiment 2 showed that a peripherally presented distractor face containing a disfiguring or occluding feature did not influence covert orienting of attention (as measured by the cueing costs), over and above of the presence of a face per se. Moreover, there was no effect of the type of distractor face on valid or invalid trials. We reasoned that on invalidly cued trials, the presence of the disfiguring or a salience-matched occluding control feature on the distractor face might hold attention, reducing efficient engagement towards the target location. This was not the case. Our results further showed that the perceptual interpretation of the feature on the distractor faces — whether perceived as integral or separate from the face — did not influence the cueing costs either, since these costs were alike for faces with a disfiguring and occluding feature. Finally, one might argue that the lack of an effect of feature type with the salience-matched distractor stimuli might relate to the lack of a reliable cueing effect per se — perhaps observers might not be using the cue at all. However, an analysis of the data for the full face set (including non-salience-matched stimuli) revealed reliable RT costs by invalid cues, yet these were still not affected by the type of distractor face. In sum, Experiment 2 suggests that facially disfiguring features do not capture covert attention over and above that of salience-matched control features.

4. Experiment 3

In Experiment 3 we used a centrally presented distractor face to examine the effect of a disfiguring feature on covert attention (for a similar stimulus setup, see Brassen, Gamer, Rose, & Büchel, 2010). Using the same task as in Experiment 2, we asked whether a disfiguring feature on a foveally presented distractor face might be more likely to capture covert attention. As illustrated in Figure 3, this setup also allowed to assess whether the proximity of a salient facial feature relative to the cued focus of attention affects target discrimination. We hypothesized that, if the facial feature influences covert attention, it might do so depending on both the proximity of the feature relative to the cued location, and on cue validity, as follows: If the feature is *near* the focus of attention, then speed of target discrimination might be *faster* when the cue is valid than when the cue is invalid. Because here attention is correctly cued to the target location, the presence of a nearby feature might facilitate to keep attention in that location. In contrast, when the feature is on the *opposite* side compared to the focus of attention, then speed of target discrimination might be faster when the cue is invalid compared to when it is valid. This effect might be expected if the facial feature captures attention and thereby makes disengagement from the invalidly cued location less efficient.

4.1. Method

4.1.1. Participants

Forty students and staff took part in the experiment for course credits or a £5 payment. There were 33 females and 7 males aged between 18 and 62 years (M = 27.2, SD = 10.0) from various ethnic backgrounds (16 White, 6 Black, 9 Asian, 2 South-East Asian, and 4 of mixed ethnicities) and there were 3 lefthanders.

4.1.2. Design, stimuli, materials, and procedure

The design was identical to Experiment 2. The stimulus displays were similar to Experiment 2 except for the following changes (Figure 3). The target was an upright or inverted T, but it was not surrounded by + signs. We simplified the target because pilot work indicated that observers could not discriminate the target patterns without a significant reduction in accuracy (compared to Experiment 2). With this change the average accuracy in Experiment 3 was comparable to that in Experiment 2 (respectively, 94.66 vs. 94.62% ; $t(70.4) < 1$, unpaired, unequal variances). The same face stimuli were used as distractors as in Experiment 2, in addition to a no-distractor condition. Targets and distractors were shown without surrounding boxes. On each trial, a central cue (< or >) directed attention to the left or right visual field for 200 ms. Following a 75 ms blank interval the target and the distractor face (if present) were presented for 200 ms. A blank screen followed the target display until a response was made, and this was followed by a 1,500 ms inter-trial interval.

Observers were familiarised with the faces as in Experiment 2. They were instructed to maintain gaze at the centre of the screen while covertly attending to the cued location, and to maintain central gaze during the presentation of the target. They were informed that the cue was 80% predictive of the target location, and that the face should be ignored. Eye position was measured from the onset of the cue until the response and a drift correction was applied every 20 trials.

4.2. Results

The data were screened using the same inclusion criteria for analysis as in Experiment 2. Trials in which the central dwell percentage in the cue-to-response time window was lower than 90%, as well as trials with responses faster than 200 ms or slower than 4 s were excluded (excluding 0.86%). Each participant had at least 95.3% of their responses retained (M = 99.1%, SD = 1.2%). Of these, correct RTs that did not exceed 3 SDs of the individual average correct RT were analysed (94% of the remaining data). As in Experiment 2 we report the results from the subset of salience-matched distractor faces. Parallel analyses of the full data replicated the reported results and these are therefore not reported.

Table 4 shows RTs and error rates on valid and invalid trials for all distractor types. Cueing costs were small compared to Experiment 2 (4 ms across conditions). We fitted RTs to an LME model with cue validity, distractor type and their interaction as fixed effects, and by-participant intercepts and by-participant slopes of cue validity as random effects. This was the first model that met the same criteria used in Experiment 2. The effect of cue validity failed to reach significance (B = -.0175, SE = .0089, t = -1.95). There was no effect of distractor type and no interaction between cue and distractor ($t < -.68$). Because of the lack of a cue validity effect for the subset of salience-matched stimuli, we also performed an analysis of the full set of feature-bearing distractor faces. This revealed the same pattern, with no reliable cue validity effects. Finally, we inspected the effect of proximity of the feature relative to the focus of attention – expressed in terms of a comparison of cue validity effects – for the full set of feature-bearing distractor faces. These effects are reported in Table S3 (Supplementary Material). There were no effects of feature proximity, that is, no differences between cue validity effects for *near* and *opposite* feature locations for any of the feature-bearing distractor faces, cf. the small numerical effects and large and overlapping confidence intervals.

4.3. Discussion

Experiment 3 showed no evidence that a disfiguring facial feature influences covert attention differently from either faces with an occluding control feature or faces without added feature. In fact, neither the (salience-matched) disfiguring or occluding features generated a reliable cue validity effect. Furthermore, the proximity of the feature did not influence cue validity effects either. The fact that no attentional capture by a disfiguring feature was observed when the distractor face was foveated (albeit being task-irrelevant) further strengthens the suggestion that covert attention is not affected by the presence of a facially disfiguring feature.

In contrast to Experiment 2, the central positioning of the distractor reduced the cue validity benefit and sometimes reversed it into a cost — an RT benefit for un-cued locations or inhibition of return (Klein, 2000). It would appear that the distractor interfered differently with the ability to engage attention at the cued location for different observers: inspection of the distribution of cue validity effects across distractor conditions between observers showed substantial individual differences. It is well-known that central distractors can reduce or prevent attentional capture by peripheral stimuli (Folk, Ester, & Troemel, 2009), but a more detailed exploration of this possibility is beyond the scope of this paper. With regard to the purpose of the present study, however, the finding that facially disfiguring or occluding features on foveally presented distractor faces do not differ in their impact on covert attention is consistent with the results of Experiment 2.

5. Experiment 4

Experiment 4 examined the effect of disfiguring features on *overt* orienting — the directing of visual attention by means of eye movements in order to bring into foveal vision locations of interest. The motivation for this study was twofold: First, given that covert shifts of attention drive overt shifts (Carrasco, 2011), and given the evidence in Experiments 2 and 3 that covert attention is not affected by a facial feature on either a peripheral or central distractor, it is relevant to assess the impact of such features when covert and overt attention are explicitly directed to a task-relevant face. If that impact is equally sparse under these conditions, then the effects in Experiments 2 and 3 are unlikely to be due to the task-irrelevance of the faces, or to attention being covert. Second, previous evidence suggests that facially disfiguring features influence how observers attend to task-relevant faces (Ishii et al., 2009; Madera & Hebl, 2012). These findings, however, were based on comparisons between faces containing a disfiguring feature and faces without added feature — thereby raising the question whether the effects of the feature are due to its visual salience. As our study included a condition with faces containing an occluding control feature, it allowed us to examine whether observers' attention is drawn in equal measure to facial features that have a distinct perceptual interpretation.

In Experiment 4 observers viewed peripherally presented faces for 2 seconds in anticipation of an attractiveness rating. Starting from a central position, the scan path, the location and the duration of successive fixations towards the face were analysed as a function of facial interest areas (the eye region and the face half containing the feature), as well as the presence and type of an added facial feature. The eye region was chosen because of its status as a preferentially inspected region during face viewing (Barton et al., 2006; Vinette, Gosselin, & Schyns, 2004; for a recent review, see Itier, 2015). The presence of a salient feature elsewhere on the face might reduce the likelihood of fixating the eyes. Further, if the interpretation of the facial feature —as an intrinsic part of the face— influences overt attention one might expect more fixations to faces that contain disfiguring than occluding features. Finally, the impact of the disfiguring feature might also be evidenced by it attracting more attention over time during the presentation of the face. For instance, observers' gaze might revisit the same parts of the face, resulting in a greater number of recurrent fixations. Salient features might be re-fixated during presentation, and given the particular interpretation of disfiguring features one could expect more recurrent fixations towards disfigured faces.

5.1. Method

5.1.1. Participants

Thirty students and staff took part in return for course credits or a £5 payment. None had taken part in the previous studies. There were 23 females and 7 males, aged between 18 and 54 years (*M* = 30.7, *SD* = 10.8) and from various ethnic backgrounds (21 White, 1 Black and 8 Asian); there was 1 lefthander.

5.1.2. Stimuli, materials and design

The experiment was programmed and run using the same equipment as Experiments 2 and 3. Eye tracking setup, calibration and monitoring were similar to Experiments 2 and 3 except for the task instructions. From the original set of 80 face identities, 72 face identities (36 female and 36 male) were used in this experiment to create a set of 72 images (footnote

7) Each participant saw each face identity only once, in one of the 5 conditions (normal, left- or right-side disfigured, and left- or right-side occluded). A new random allocation of facial identities and conditions was generated for each participant with the restriction that conditions were equally represented in male and female faces and for left and right visual field locations. Each face image was 600 pixels wide (10.35˚ at a viewing distance of 80 cm) and its height varied between 700-900 pixels (12.33˚- 15.70˚). Each face was presented on a white background at a distance (from the centre of the image) of 10.08˚ to either the left or the right of the centre of the monitor. The distance from the centre of the monitor to the nearest vertical edge of each image was 4.91˚ on either side.

5.1.3. Procedure

Each participant was tested individually in a session lasting about 20 minutes. Instructions included a familiarisation with example faces in the same way as in Experiments 2 and 3. Each trial began with a 500 ms display of a central black fixation cross. After the fixation cross disappeared a face was shown on the left or right side of the screen for 2 seconds. Eye tracking data collected during this 2-second period were stored for offline analysis.

Participants were instructed to maintain eye gaze at the centre of the screen, and to freely explore the face as soon as it appeared and to judge its attractiveness. After the face disappeared, a question mark appeared on the screen with below it a 7-point rating scale with 1 indicating “very unattractive” and 7 “very attractive”. The participant had to enter the number corresponding to their rating after the face had disappeared, without time restrictions. No responses were allowed or possible during the presentation of the face. To avoid any response or experimenter bias, the experimenter did not see the faces shown to the participant during the experiment and had no access to either the face conditions shown on each trial, or the responses provided. Each participant was encouraged to give their honest response and was informed that the faces were of unfamiliar persons who would have no access to their ratings. Each set of 72 trials was presented in 3 blocks of 24 trials. A drift check was performed every 8 trials and a recalibration and validation was performed after each block of 24 trials. No practice trials were given. Eye gaze from the participants' right eye was sampled continuously at 1 kHz and was stored for offline analysis alongside ratings.

5.2. Results

We report here analyses of eye tracking performance from the set of salience-matched face stimuli as determined in Experiment 1. We also performed parallel analyses using the entire stimulus set of faces used in this experiment, but unless stated otherwise, these analyses yielded the same pattern of results and are therefore either not reported.

5.2.1. Attractiveness ratings

Normal faces were rated as more attractive than occluded faces, which were rated as more attractive than disfigured faces (normal, $M = 3.84$, $SD = 1.59$; occluded, $M = 3.44$, $SD = 1.52$; disfigured, $M = 3.05$, $SD = 1.47$). To evaluate these differences, the original ratings were fitted with LME models following the same method as used previously, with face location (left vs. right visual field), face type (normal, disfigured, occluded), feature location within the face (no feature, left-side or right-side) and all their interactions as fixed effects, and by-subjects and by-item intercepts as random effects; all fixed effects were contrast-coded (e.g., left visual field = -0.5, right visual field = 0.5). A model including all face types (normal, disfigured, occluded) showed a reliable effect of face type ($B = .3367$, $SE = .0889$, $t = 3.78$) and no other effects ($|\, t \,| < 1.09$). Subsequent fitting for each combination of face type showed that normal faces were more attractive than both occluded faces ($B = -.7477$, $SE = .1688$, $t = -4.42$; other effects, $|\, t \,| < 1.47$) and disfigured faces ($B = 1.4606$, $SE = .1781$, $t = 8.19$; other effects, $|\, t \,| < .40$). Similarly, perceived attractiveness was lower for disfigured than occluded faces ($B = .3079$, $SE = .0810$, $t = 3.80$; other effects, $|\, t \,| < 1.38$).

5.2.2. Eye tracking analysis

We used linear mixed effects and general linear mixed effects (GLME) models to fit the number of fixations on the face per observer per trial, and fixation durations and percentages of recurrent fixations (both log-transformed), with face location, face type, and feature location (as well as all of their interactions) as fixed effects, and by-subject intercepts as a random effect. The percentage of recurrent fixations on each trial was determined using recurrence quantification analysis as described by Anderson, Bischof, Laidlaw, Risko, and Kingstone (2013). For each fixation sequence we determined the percentage of fixations revisiting other fixations (over all possible time lags) within a 64-pixel radius centred on the fixation location. In addition, for fixations on the face we used generalized linear mixed models to model the fixation probability (as log-transformed odds) on the eye region, and on the face half containing the disfiguring/occluding feature as a function of face location, face type and feature location. The GLME models were implemented using the *glmer* function in the *lme4* package, with the *bobyqa* optimizer and a logit link function.

1. Number of fixations on the face. Observers fixated more often occluded (6.35) than disfigured (6.19) or normal (6.12) faces, $B = .1860$, $SE = .0737$, $t = 2.52$. In the subset of salience-matched faces, however, this effect, although numerically preserved (occluded vs. disfigured vs. normal, 6.31 vs. 6.29 vs. 6.07), was not reliable, $B = .1226$, $SE = .1127$, $t = 1.09$.

2. Total and individual fixation durations. The total looking time (the sum of fixation durations on the face) for the salience-matched faces is shown in Figure 4A. Observers did not spend more time looking at particular face conditions. This was confirmed by an LME model of total looking times with face location, face type, feature location and their 2- and 3-way interactions as fixed effects, and participants and face identity as random effects: There were no reliable main effects ($| t | < 1.1$), and no two-way or three-way interactions ($| t | <$

1.7). Because the sum of fixation durations is in part determined by the number of fixations on the face, we also analysed the individual fixation duration to each face type: these were virtually identical for disfigured (258 ms), occluded (257 ms) and normal (254 ms) faces, $t < 1$ (all other effects, $| t | < 1.30$).

3. Fixations to the eyes. Figure 4B shows the probability (expressed as log odds) of fixations falling in the eye region compared to the rest of the face for the salience-matched faces; the same probability as a function of fixation order for the full stimulus set is shown in Figure S1 (Supplementary Material). Positive values indicate that more fixations fell on the eye region. The odds of fixating the eyes were higher for normal (1.05) than for disfigured (0.95) or occluded faces (0.77) ($B = -.2015$, $SE = .0716$, $z = -2.81$, $p < .005$). Also, marginally more fixations were made to the eyes when the added (disfiguring or occluding) feature was located to the right of the observer (i.e., on the left half of the face) than to the left (i.e., on the right face-half) (odds, 0.89 vs. 0.82), ($B = -.1392$, $SE = .0714$, $z = -1.95$, $p = .051$); there were no other effects ($| z | < 1.80$, $p > .071$). A separate analysis for disfigured and occluded faces revealed the same effect of feature type: the probability of fixating the eyes was higher when the face contained a disfiguring (rather than an occluding) feature ($B = -0.1977$, $SE = 0.0717$, $z = -2.75$, $p < 0.006$). This analysis also revealed an effect of face location: when the face was in the right visual field, more fixations to the eyes were made than when it was in the left visual field (odds, 0.93 vs. 0.90, $B = 0.1525$, $SE = 0.07186$, $z = 2.123$, $p < 0.034$). There was no effect of feature location ($B = -0.1250$, $SE = 0.0715$, $z = -1.748$, $p = 0.080$) and no interactions ($| z | < 0.576$).

4. Fixations to the feature location. Figure 4C shows the probability of fixations on the right face-half as a function of face type and feature location for the salience-matched faces; Figure S2 in Supplementary Material shows the same probability (log odds) as a function of fixation order for the entire set of faces. Positive values indicate a bias for the right face-half. Normal faces showed a small bias towards the right face half. Feature-bearing faces elicited more fixations on the face half containing the feature across all conditions; this bias also appeared to be stronger for right-sided than left-sided features (Figure 4C). A GLME model of the fixation probabilities revealed a reliable effect of feature location ($B = -.6326$, $SE = .0667$, $z = -9.48$, $p < .001$). However, feature location did not interact with feature type ($B = 0.1346$, $SE = 0.1347$, $z < 1$) and there were no other effects ($| z | < .70$).

5. Recurrent fixations. Figure 5 shows the percentage of recurrent fixations as a function of visual field, face type and feature location for the salience-matched faces. There were more recurrent fixations to faces in the left than in the right visual field (16.78 vs. 16.03%; $B = -.0474$, $SE = .0212$, $t = -2.23$). There were also more recurrent fixations to normal faces (17.74%) than to disfigured or occluded faces (16.52 vs. 14.99%; $B = -.0800$, $SE = .0259$, $t = -3.08$). Disfiguring features also elicited more recurrent fixations than occluding features, ($B = -.0796$, $SE = .0261$, $t = -3.04$). Finally, there was a three-way interaction between visual field, face type and feature location ($B = -.2341$, $SE = .1047$, $t = -2.24$): Figure 5 suggests that the latter finding stems from disfigured faces showing opposite differences in fixation recurrences (less recurrences for left-disfigured faces in the left visual field and for right-disfigured faces in the right visual field), while those differences between occluded faces are smaller. There were no other effects (all $| t | < 0.49$).

5.3. Discussion

In Experiment 4 we employed an attractiveness rating task to examine whether overt orienting of attention to faces is influenced by the presence of a disfiguring feature, compared to faces with a control feature or no added feature. This task also allowed us to validate our facial feature manipulations and the different perceptual interpretations they elicit. Attentional allocation was assessed by analysing the eye fixation patterns of the observers. Faces with disfiguring features attracted more fixations on the eyes and incurred a higher number of recurrent fixations compared to faces with occluding features. This demonstrates that disfiguring facial features influence the allocation of overt attention differently compared to occluding (control) features, even when the feature types were matched in terms of visual salience.

Some aspects of our data suggest that the orienting of attention to the faces in our attractiveness rating task may also have been driven by other factors rather than feature type. These effects were particularly prominent when considering the full stimulus set of faces (see Supplementary Material). For example, while, unsurprisingly, more fixations were directed towards the face half containing the disfiguring or occluding feature, this bias was stronger for right-sided than for left-sided features. Thus, overt attention was more directed towards right-sided features, although this bias was not accompanied by differences in attractiveness ratings. Spatial (left-right) asymmetries in face perception have been found before (Bourne, 2011; Burt & Perrett, 1997), but they tend to favour the left face-half. Concerning facial disfigurements, there is some evidence that right-sided unilateral cleft lips are judged as more disfiguring than left-sided ones, but this finding has been attributed to physiognomic rather than perceptual differences (Billaud Feragen, Semb, & Magnussen, 1999).

In sum, Experiment 4 suggests that both disfiguring and occluding features can modulate the distribution of overt attention towards the face. Crucially, it also provides evidence that the impact of disfiguring features on overt attention differs from that of occluding features.

6. General Discussion

Taken together, Experiments 2 - 4 demonstrate that facially disfiguring features (FDFs) have the potential to affect attentional allocation, although their impact depends on the type of attention considered: During overt attention - as manifest in Experiment 4 in the increased number of eye fixations and recurrent fixations - disfiguring features exert a level of control that is not just driven by their visual distinctiveness, i.e. their salience, but also by their perceptual interpretation, i.e. by the fact that such features are seen as an intrinsic part of the face. By contrast, no such effect of perceptual interpretation was found in the case of covert attention, regardless of whether covert attentional allocation was induced by a distractor presented in the peripheral (Experiment 2) or central (Experiment 3) visual field.

Our results confirm, but also significantly extend, earlier findings regarding the impact of facial disfigurements on attentional control. Most previous research in that field focused on the deployment of overt visual attention by tracking the eye movements of observers who were freely scanning faces with disfiguring features (Ishii et al., 2009; Meyer-Marcotty et al., 2010; Madera & Hebel, 2012). The deflection of gaze towards FDFs reported in that earlier work is consistent with the fixation data in Experiment 4 of our study. However, when visual saliency was taken into account, by contrasting disfigured faces against occluded faces within our salience-matched stimulus set, only the effects on the fixation frequency on the eye region and the frequency of recurrent fixations proved to be statistically reliable. This suggests that previous research may have overestimated the effect of FDFs on attentional control by contrasting disfigured faces with normal faces only, thus confounding the relative contributions of salience and perceptual interpretation. Our study also is – to our knowledge - the first to assess the impact of FDFs on overt and covert attention for the *same* face stimulus set. Here the results of Experiment 2 and 3 suggest that this impact may be entirely mediated by the salience of visual disfigurements, i.e. their relative conspicuity within the spatial context of a face. By contrast, their perceptual interpretation, i.e. whether these features are seen as part of a face or not, was found to play no significant role.

Disfigured and occluding (control) features in our study were not only matched in terms of their salience relative to their surrounding face context, but were also similar in colour and texture. This was to minimize any effects of a differential semantic interpretation based on differences of such local stimulus properties. Indeed some previous studies considering the effect of FDFs employed deliberate manipulations of semantic associations, for example by explicitly priming observers to associate FDFs with disease (Ackerman et al., 2009) or facilitating such connotations implicitly through contextual information (Blascovich et al., 2001; Ryan et al., 2012). These studies provide evidence that attention to FDFs may be modulated to some extent by their meaning, i.e. their potential to signal threat (here: disease). However, these experiments again contrasted disfiguring and normal faces only, thus preventing a proper evaluation of the relative effects FDFs exert on attentional control through their salience and perceptual interpretation prior to those induced by their semantic evaluation.

One limitation of our study concerns the nature of the facial disfigurements used in our experiments. These were distinctive and realistic (as also confirmed by informal comments of our observers) but they involved a featural disfigurement, consisting of the *addition* of visual information, which could be perceptually segregated without affecting the generic structure (i.e., the configuration of mouth, nose and eyes) of the face. However, other types of disfigurement (e.g., cleft lip and palate) may affect the structure of a face much more profoundly, and may be perceptually more embedded within the face. Given the well-known importance of configural processing in face perception (see e.g. Maurer, Le Grand & Mondloch, 2002; Piepers & Robbins, 2012) such *structural* deformations might have the potential to affect attentional processes more strongly than a mere *featural* disfigurement. However, so far no systematic comparisons regarding the impact of different types of FDFs have been carried out.

In conclusion, the results of our study confirm the findings of earlier research that facial disfigurements affect the allocation of visual attention. However, our analysis qualifies those earlier observations by demonstrating that these attentional effects are to some extent attributable to the particular visual conspicuity, i.e. the salience, of those disfigurements. Only for overt - but not covert - attention did we find evidence that attention is also affected by the perceptual interpretation of these disfigurements as being an intrinsic part of the face. Together, our results suggest that biases in the behavioural responses and cognitions towards persons with facial disfigurements might be predominantly grounded in other processes than initial attentional capture.

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Declaration of competing interests

The authors declare no competing interests.

Figure 1. Example female and male faces containing either no added feature (A), a disfiguring feature (B) or an occluding (C) feature.

(A) NORMAL

(B) DISFIGURING

(C) OCCLUDING

Figure 2. Time course of events during a trial in Experiment 2.

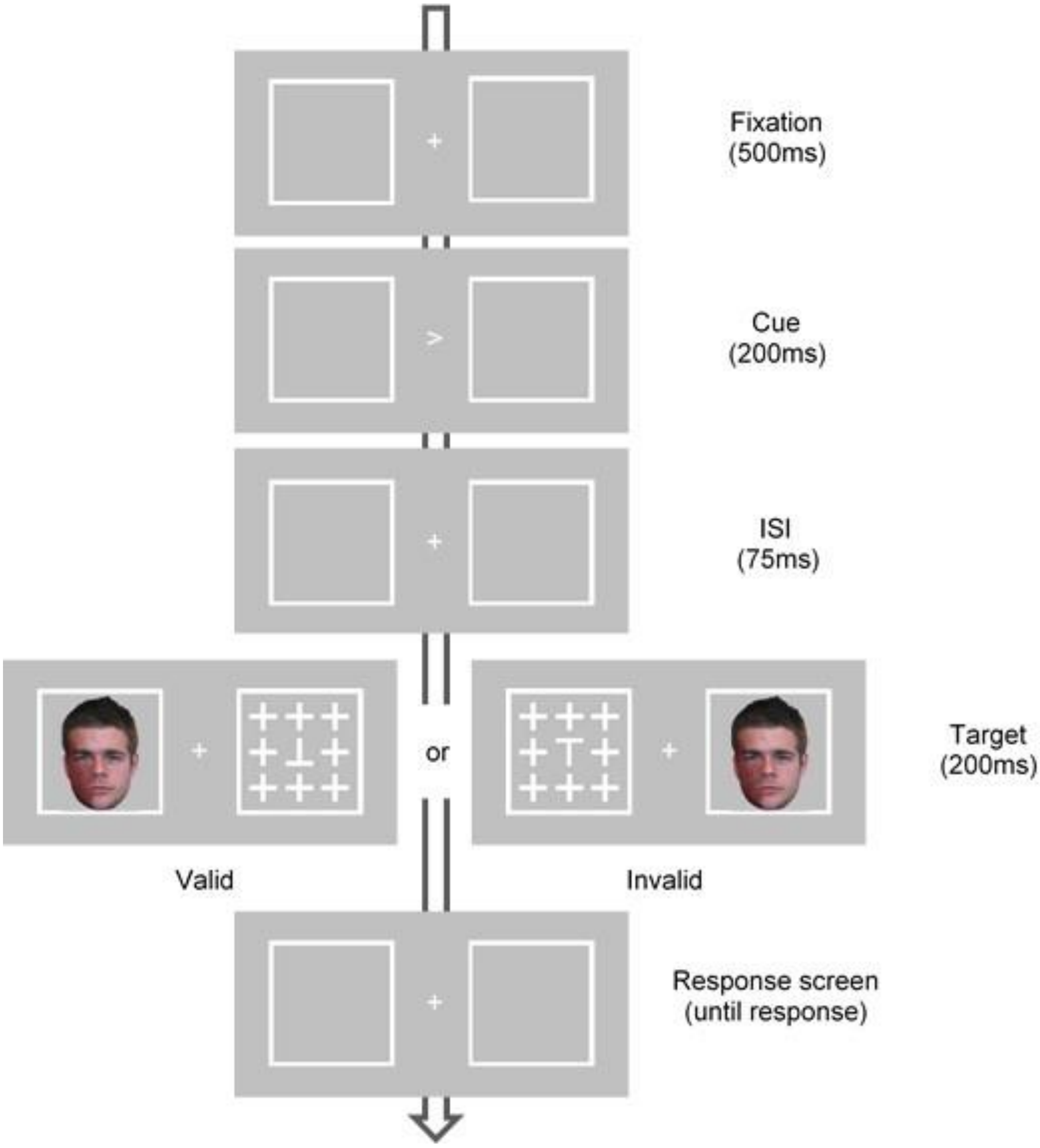


Figure 3. Experiment 3: Illustration of the spatial proximities of the location of cued attention (indicated by the dashed circle) relative to the locations of the facially disfiguring feature and the target stimulus. (A) Following a valid cue, the focus of attention was on the target location, and could be near or far from the facial feature. (B) Following an invalid cue, the focus of attention was on the opposite side to the target location, but either near or far from the facial feature.

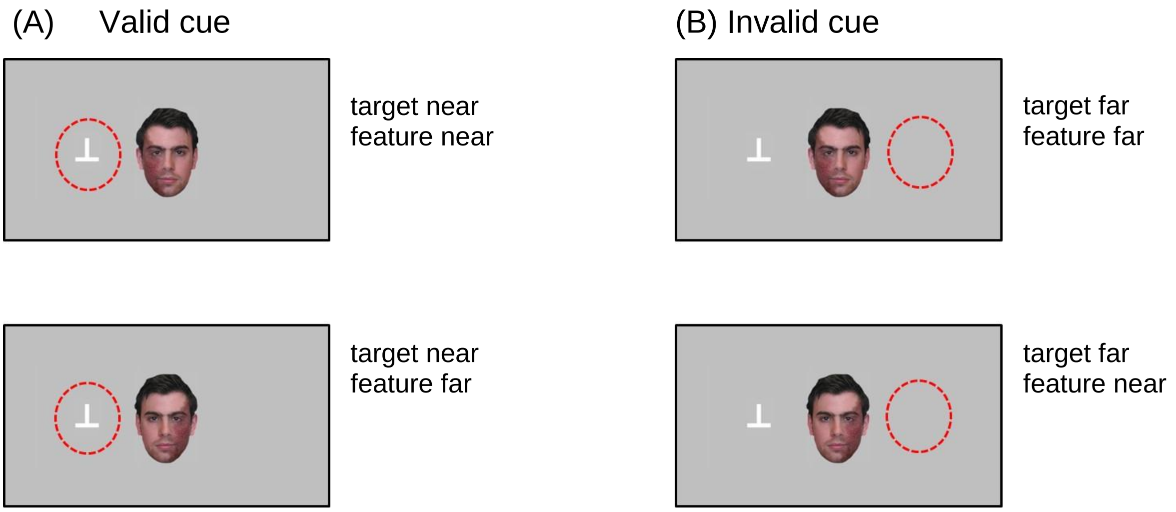
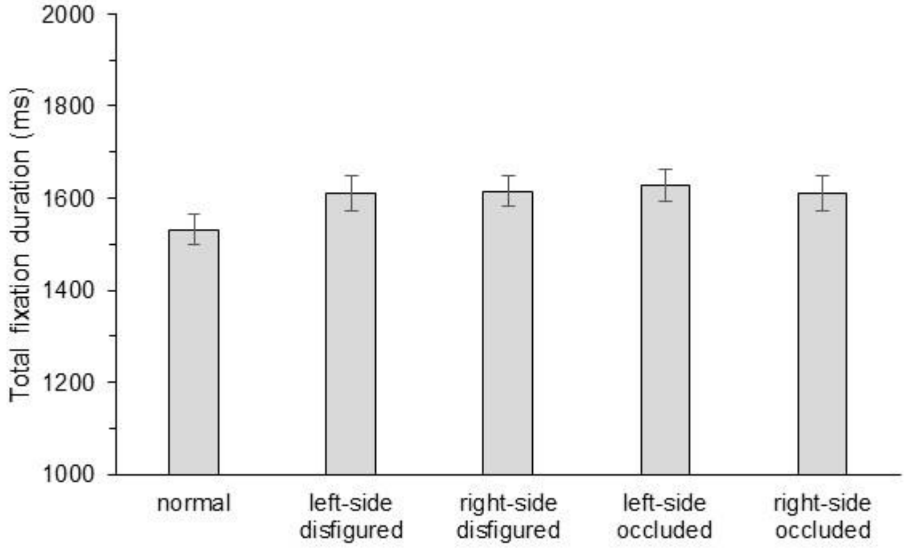


Figure 4. Experiment 4: Total fixation duration on the face (ms, $M \pm 95\%$ CI) (A), probability (in log odds) of fixations falling on the eye region (B), and probability (in log odds) of fixations falling on the right face-half (C).

(A)



(B)

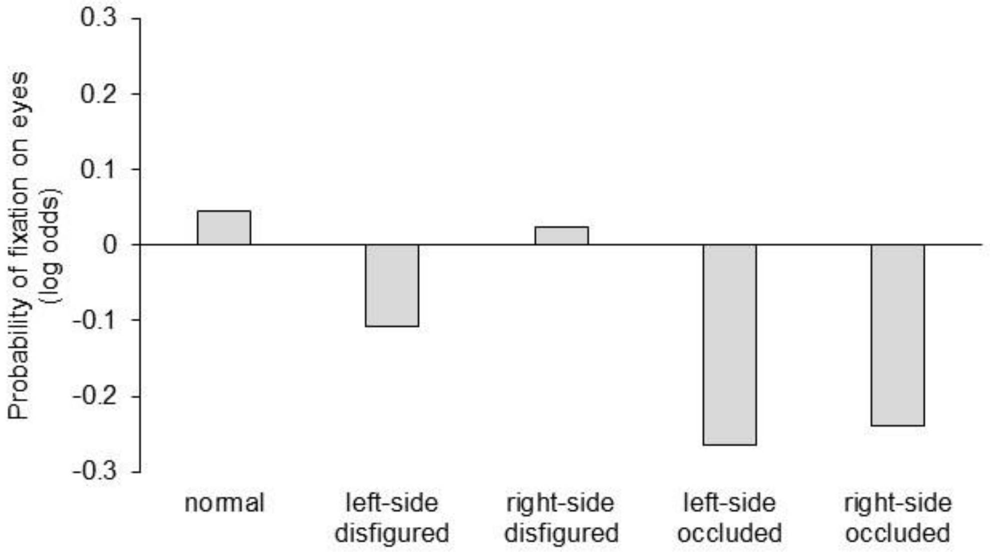


Figure 4 (continued)

(C)

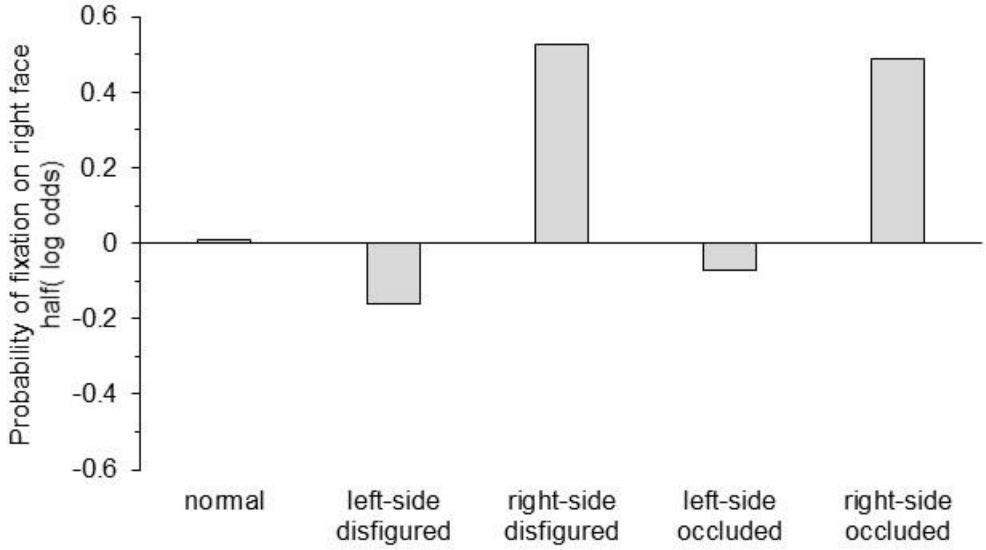
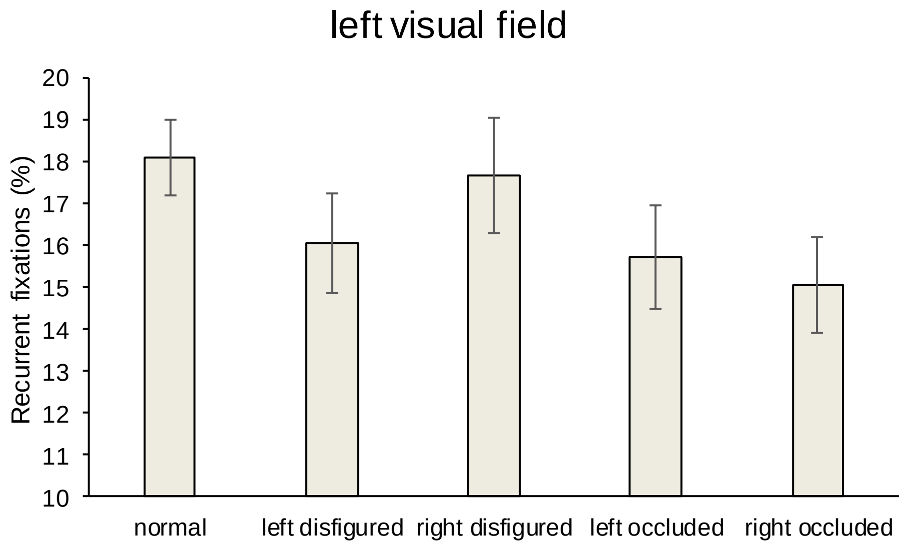


Figure 5. Experiment 4: Recurrent fixations (%, *M* ± 95% CI) as a function of visual field location of the face, face type and feature type.



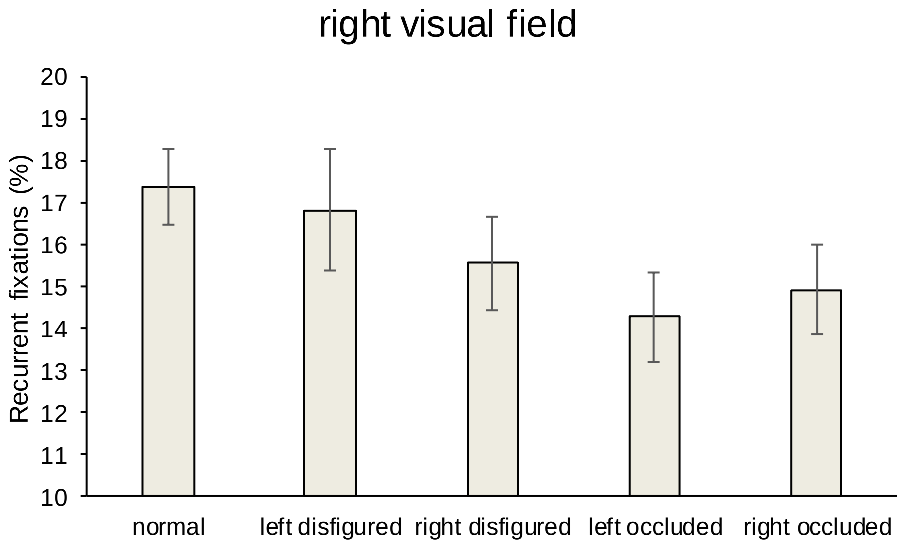


Table 1

Experiment 1: Sensitivity and Decision Criteria (Average and 95% Confidence Intervals) of Discrimination Between Normal, Disfigured and Occluded Faces

	Sensitivity		*Criterion*	
Condition	*d'*	*95% CI*	*τ*	*95% CI*
normal vs. disfigured	4.84	[4.11, 5.68]	2.90	[2.46, 3.45]
normal vs. occluded	5.55	[4.66, 6.70]	2.78	[2.36, 3.27]
disfigured vs. occluded	5.10	[4.29, 6.10]	2.51	[2.16, 2.92]

Table 2

Experiment 1: Reaction Times (ms) on Same and Different Trials as a Function of Face Pair

Response and face pair	*RT (ms)*	95% *CI*	*Accuracy (%)*
Same			
Normal	713	[702, 724]	97.6
Disfigured	809	[794, 824]	91.8
Occluded	763	[751, 776]	89.5
Different[a]			
Normal vs. disfigured	833	[815, 850]	89.9
Normal vs. occluded	743	[730, 756]	97.2
Disfigured vs. occluded	794	[780, 809]	96.0

[a]Conditions compared on different trials are collapsed across visual field location (e.g., ‘Normal vs. Disfigured includes both normal-disfigured and disfigured-normal pairs).

Table 3

Experiment 2: Mean Correct Response Times (in ms), Error Rates (%), and Cue Validity Effects (in ms) as a Function of Distractor Condition

Distractor condition	Valid trials		Invalid trials		Validity effect	
	RT	*Errors (%)*	*RT*	*Errors (%)*	*ms*	[95% CI_t]
no face	570.2	(4.48)	612.0	(6.28)	41.8	[30.6, 53.0]
normal	582.1	(5.13)	594.8	(5.46)	12.7	[-6.9, 32.3]
disfigured						
left face-half	582.3	(5.53)	588.3	(4.82)	6.0	[-13.6, 25.6]
right face-half	579.2	(5.49)	598.7	(4.76)	19.5	[-0.1, 39.1]
occluded						
left face-half	587.7	(5.14)	597.9	(6.15)	10.2	[-9.4, 29.8]
right face-half	583.0	(5.41)	601.9	(7.14)	18.9	[-0.7, 38.5]

Note. The cue validity effect in each distractor condition represents the subtraction of RTs of valid from invalid trials, and its 95% confidence interval (2-tailed *t*, adjusted for repeated measures) is presented in square brackets. Left and right face halves are labelled relative to the observer.

Table 4

Experiment 3: Mean Correct Response Times (in ms), Error Rates (%), and Cue Validity Effects (in ms) as a Function of Distractor Condition

Distractor condition	Valid trials		Invalid trials		Validity effect	
	RT	*Errors* (%)	*RT*	*Errors* (%)	*M*	[95% CI]
no face	556.7	(4.79)	561.5	(5.61)	4.8	[-6.5, 16.1]
normal	553.9	(5.57)	564.4	(6.49)	10.5	[0.6, 23.2]
disfigured						
left face-half	556.7	(5.17)	552.1	(5.26)	-4.6	[-7.5, 15.1]
right face-half	560.8	(5.70)	569.2	(6.31)	8.3	[-2.8, 19.8]
occluded						
left face-half	558.8	(6.13)	555.0	(5.96)	-3.8	[-20.5, 2.1]
right face-half	553.1	(5.00)	574.4	(5.61)	21.3	[-10.0, 12.6]

Note. The cue validity effect in each distractor condition represents the subtraction of RTs of valid from invalid trials, and its 95% confidence interval is presented in square brackets. Left and right face halves are labelled relative to the observer.

Footnotes

1 This area was defined as the bounding rectangle between the left and right cheeks, and between the upper edge of the eye brows and the edge of the chin. The surface area of the disfigurement was likewise defined as the smallest bounding rectangle that fitted its borders on all sides. This includes areas that border on the disfiguring feature but that have the face's original texture: the actual area of the disfigurement thus was smaller.

2 The disfiguring feature was around 2.5 times larger in size than the occluding feature—as by comparing the bounding rectangle surrounding the disfiguring feature to the occluding feature. However, the location (on the cheek) of the largest area of the disfiguring overlapped with that of the occluding feature.

3 The LME analysis was performed in *R* (v. 3.4.0, R Development Core Team, 2009) using the *lme4* package (Bates, Maechler, Bolker, & Walker, 2015) on unaggregated data. Log-transformed RTs were modelled as a function of the variables of interest using the *lmer* function (using restricted maximum likelihood); the *bobyqa* optimizer algorithm was used to reduce failures to converge. Linear mixed effects (LME) models have important advantages over ANOVA which makes them an increasingly popular model for data analysis in experimental psychology (Baayen, Davidson, & Bates, 2008). First, LME models do not depend on assumptions of normality and of independence of observations. Second, in contrast to ANOVAs, slopes and intercepts in LME models are computed on *unaggregated* data per participant, thereby yielding a description of effects not distorted by data aggregation. Third, LME models allow the estimation of fixed and random effects and their interactions —by participants, by stimuli, and by their interactions with fixed effects. In our analyses we evaluated individual differences by participants and by items (the face stimuli) in the effects of our variables of interest.

4 As the closest edge of each box on either side was 3.17˚ from the centre, it did not overlap with the central area of interest.

5 Accuracy was analysed but yielded either no effects or effects similar to RTs, and therefore these are not reported.

6 The temporal structure of the events during each trial was identical to that of Experiment 1, and so was the cue validity, and both conditions would typically lead to a benefit from cue validity.

7 A prior rating study was conducted in which 20 participants rated 80 faces in their original state; the 8 face identities that were removed consisted of faces that had the lowest or highest possible rating of attractiveness.