The time-course of contextual valence and self-relevance effects on the perception of faces with direct versus averted gaze

by

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Abstract

We see faces every day within a rich situational context. Previous ERP research has demonstrated that priming faces with contextual sentences varying in self-relevance and valence alters electrocortical and emotional responding to them, though the time-course of these effects is still unclear. It is also unclear if these effects interact with another cue that inherently contains emotional and self-referential information: whether or not the face is looking at the participant. We primed direct and averted gaze neutral faces (gaze manipulation) with emotional sentences to give them context. These sentences contained positive or negative opinions (valence manipulation) that the face held of the participants or of someone else (self-relevance manipulation). After reading each sentence, participants viewed the corresponding face and rated how positive or negative, and how affectively aroused, it made them feel. Eye-tracking enforced sentence reading and face fixation, while ERPs recorded at face onset tracked the time-course of when context and gaze effects interacted. Faces put into self-relevant contexts were more arousing than those in other-relevant contexts, and elicited different ERP waveforms just 150ms post-face, earlier than previously reported. This self-relevance effect was modulated by valence at both the behavioural and ERP level. Finally, faces put into positive self-referential contexts elicited different N170 ERP amplitudes depending on gaze direction, interacting during the time window thought to reflect the structural encoding of the face. These findings were paralleled in our behavioural measures, where positive self-referential faces made participants feel more positive if they had direct rather than averted gaze. These results indicate that the contextual cues of self-relevance and valence impact early visual perception of neutral faces in a complex and nuanced manner, interacting with gaze direction. They emphasize the importance of studying the effect of gaze cues on face perception within context mimicking the complexities of real world interactions.

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Chapter 1: INTRODUCTION

To facilitate any social interaction, we extract a multitude of information from the people around us. Much of this information comes directly from the faces of others, including both static (e.g., gender, attractiveness) and dynamic facial cues (e.g., gaze, emotional expression). However, we almost never see faces, or facial cues like gaze, in isolation; we see those around us within a rich social environment that provides context (see Barrett et al. 2011 for a brief review), including how relevant to us (self-relevance) and how positive or negative (valence) the situation is. Intuitively, self-relevance and valence appear to have a large impact on our emotional responses to faces; imagine how differently an observer would feel facing someone who has just insulted them versus someone who has just complemented them, and how different their feeling would be if they witnessed that same person insulting or complementing someone else. There has been scarce research investigating how these context cues affect face perception, and no research investigating how facial and situational context cues interact. Studies which present faces within rich social environments are needed to fully address these questions.

Self-relevance is a powerful cue, biasing information processing towards relevant stimuli and affecting many domains of cognition (Schmitz & Johnson, 2007), including attention (Bogels & Mansell, 2004), memory (Symons & Johnson, 1997), and emotional processing (Herbert, Pauli, & Herbert, 2010). It has been proposed that self-referential processing is adaptive during social situations because it allows an observer to draw upon their own experience to infer the mental states of others (Frith & Frith, 2001; Mitchell, Banaki & Macrae, 2005). Accordingly, self-referential processing is altered in those with social impairments, including individuals with autism (Henderson, et al., 2009; Mundy, Gwaltney & Henderson, 2010; Burrows, Usher, Mundy & Henderson, 2017), high social anxiety (Blair et al. 2008;

Moscovitch, Orr, Rowa, Reimer & Antony, 2009) and depression (Auerbach, Stanton, Proudfit, & Pizzagalli, 2015).

While previous studies have demonstrated the positive association between self-referential processing and social functioning, very little research has investigated the mechanism behind it. To address this gap, investigations of how self-referential processing affects the core processes which facilitate social functioning, including face perception, are needed. Schwarz et al. (2013) and Wieser et al. (2014) asked participants to report their emotional response (arousal and valence) to seeing neutral faces primed by contextual sentences varying in self-relevance (referring to the participant or someone else) and valence (positive or negative sentences). Both studies found that these context cues had a strong impact on emotional responding to faces. Faces preceded by self-relevant statements were more arousing than those preceded by other-relevant statements, and those preceded by negative sentences made participants feel more negative than those preceded by positive comments. Contextual valence and self-relevance also interacted, such that faces preceded by positive statements were responded to most positively if the statement was also self-relevant instead of other-relevant. In contrast, faces preceded by negative statements were responded to more negatively if the statement was self-relevant.

Wieser et al. (2014) used event related potentials (ERPs) time-locked to face presentation to track the time-course of these context effects on face perception, specifically investigating ERP time windows implicated in early face perception and emotional processing. The N170 is the earliest reliable face sensitive component, occurring over occipitotemporal sites approximately 170ms after face presentation. It is thought to reflect the initial process of integrating facial features into a holistic percept (Eimer, 2000; Sagiv & Bentin 2001). In contrast, the Early Posterior Negativity (EPN) and Late Positive Potential (LPP) are thought to reflect later, more elaborate cognitive processing. These components are not face-specific, but are characterized by responsivity to emotional stimuli, suggesting they may be affected by emotional context. The EPN is characterized by an enhanced negativity over occipitotemporal sites approximately 220-300ms following the presentation of positive or negative stimuli relative to neutral stimuli, (e.g., Herbert et al. 2008; Kissler et al. 2009; Schupp et al. 2006) or negative stimuli relative to positive stimuli (Rellecke, Palazova, Sommer, & Schacht, 2011; Rellecke, Sommer, & Schacht, 2013; Schupp, Junghöfer, Weike, & Hamm, 2004; Neath & Itier, 2015). This enhanced negativity has been found with a variety of stimuli including emotional faces (Mühlberger et al., 2009) and adjectives (Herbert et al. 2008; Kissler et al. 2009). The LPP, occurs approximately 400-600ms over frontocental and centroparietal sties, and is similarly enhanced for positive and negative stimuli relative to neutral stimuli (Dillon, Cooper, Grent, Woldorff, & LaBar, 2006; Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000).

While the N170 was found unaffected by context, the EPN was modulated by contextual valence, with a greater negativity elicited by faces placed into positive and negative contexts relative to neutral contexts (Weiser et al., 2014). Contextual self-relevance modulated both the EPN and LPP. There was a greater negativity elicited by self-relevant faces than other-relevant faces over occipitotemporal sites during the EPN time window, and a corresponding right-lateralized positivity for self-relevant faces over frontocentral and centroparietal sites during the LPP time window (Weiser et al., 2014). Thus, despite the fact that the ERPs were elicited by neutral faces, which contain no affective value themselves, the emotional context they were placed into impacted face perception during time windows previously associated with the perception of emotional stimuli.

Despite self-relevance and valence interacting with each other at the behavioural level, no interaction was found at the ERP level. Weiser et al., (2014) interpreted this as an indication that valence and self-relevance are processed independently in the brain, but it is possible that these factors interact within a time window that they did not analyze; the a priori selection of specific time windows to investigate might have resulted in missing effects occurring at earlier or later times. In particular, an examination of the ERP waveforms in this study (Weiser et al., 2014, figure 6) suggests that self-relevance might actually impact face perception earlier than the EPN and LPP. Furthermore, it is also possible that N170 context effects might have previously been washed out as a result of where participants were fixating. The N170 is influenced by where participants look on the face (Nemrodov et al. 2014; Neath & Itier, 2015; Neath-Tavares & Itier, 2016), and preliminary eye-tracking research shows that certain context cues can change where participants visually sample information as immediately as the first face fixation (Aviezer et al. 2008).

While the studies by Schwarz et al. (2013) and Wieser et al. (2014) are a good first step in identifying how and when contextual cues impact face perception, it remains to be seen how these context cues interact with facial cues. In particular, it should be noted that all of the faces used had direct gaze, which has been implicated itself in self-referential processing (see Conty et al. 2016 and Hamilton 2016 for relevant reviews). By observing whether a person is looking at or away from us, we can infer that they are either thinking about us (making the face self-relevant) or someone else (other-relevant). Indeed, Kampe et al. (2003) demonstrated that making eye-contact actually activates similar brain regions as hearing one’s own name.

The perception of direct gaze has also been shown to impact emotional processing. In particular, seeing direct gaze is implicated in the experience of positive affect and is associated with increased activation in brain areas implicated in reward processing (e.g., Strick et al. 2008; Kampe et al. 2001). Faces with direct gaze are rated as more affectively arousing (Nichols & Champness 1971; Conty et al. 2010) and attractive (Jones et al. 2006; Kampe et al. 2001; Jones et al. 2006). Direct gaze has also been shown to impact the perception of facial emotion, (Bindemann et al. 2008; Lobmaier et al. 2008; Adams Jr & Kleck 2005; Adams & Kleck 2003), such that direct gaze faces appear to have happier expressions than averted gaze faces (Adams Jr & Kleck 2005; Adams & Kleck 2003).

To summarize, the gaze literature suggests that direct gaze is a positive, self-referential cue, suggesting that it might interact with contextual self-relevance and valence to impact emotional responding to faces. The present study adapted the contextual sentence paradigm (Schwarz et al., 2013; Wieser et al., 2014) to include neutral faces with either direct or averted gaze. Like Weiser et al. (2014), we used electroencephalography (EEG) so that we could track when gaze, valence and self-relevance cues are integrated in the brain. Instead of selecting a priori time windows to analyze, we both analyzed N170 amplitudes and performed a series of mean amplitude analyses spanning 100ms time intervals from 150 to 750ms post-face. This allowed us to fully track the time-course of effects. We used an eye-tracker to control fixation location in order to address concerns about fixation location on the N170. Finally, to maximize our chances of detecting an interaction between valence and self-relevance at the ERP level, we increased the number of trials per condition. We also chose sentences which behaviourally maximized this interaction by creating an “interaction score” for each and selecting the sentences with the highest scores (see section 2.1.2). These sentences were validated in a separate online study.

While contextual self-relevance and valence effects on face perception have not been studied often, and never in combination with gaze, we predicted that we would largely replicate the behavioural (Schwarz et al., 2013; Weiser et al. 2014) and EEG (Weiser et al. 2014) findings previously reported. However, we expected that valence and self-relevance effects would be modulated by gaze. We expected larger arousal ratings in response to self-relevant faces than other-relevant faces, though as direct gaze is implicated in self-referential processing (Conty et al., 2016; Hamilton, 2016; Kampe et al., 2003), we predicted it would provide an even stronger signal of self-relevance; self-relevant direct gaze faces should be rated as more arousing than self-relevant averted gaze faces.

Just as situational self-relevance and valence previously interacted to impact how positive or negative the faces made participants feel (Schwarz et al., 2013; Weiser et al. 2014), we expected gaze and valence would interact. We predicted that direct gaze would result in more negative valence ratings than averted gaze within *negative* contexts, but more positive valence ratings than averted gaze within *positive* contexts. As direct gaze is also associated with reward processing (Strick et al. 2008; Kampe et al. 2001), we hypothesized that the interaction between gaze and situational valence might be asymmetrical. That is, the increase in positive affect for direct gaze faces relative to averted gaze faces during positive trials might be larger than the reduction in positive affect for direct gaze faces than averted gaze faces during negative trials.

At the ERP level, we expected to replicate the enhanced EPN negativity and right-lateralized LPP positivity for self-relevant faces compared to other-relevant faces. If seeing direct gaze also puts one into a self-referential processing mode, direct gaze may work additively with contextual self-relevance, resulting in even more enhanced positivity and negativity (e.g., such that the most negative amplitudes during the EPN are elicited by self-relevant faces with direct gaze, and the most positive amplitudes are elicited by other-relevant faces with averted gaze).

Based on the observations discussed above, we believed we might also detect earlier self-relevance effects over frontal and posterior sites, before the EPN time-window. If this were the case, it would suggest that self-relevance affects earlier stages of cognitive processing than previously assumed. At the extreme was the possibility that self-referential processing may even enhance the holistic processing of faces. Here, we would expect to find that self-relevant faces elicited more negative, or earlier, N170 amplitudes than other-relevant faces.

In addition, we expected to replicate the effect of situational valence during the EPN time-window, with a greater negativity elicited by faces put into negative contexts than positive contexts. As direct gaze is a positive cue, we hypothesised that direct gaze faces might elicit more positive amplitudes during this time window as well. Finally, we predicted that our study design would give us the necessary power to detect a valence and self-relevance ERP interaction. While we had no specific a priori hypotheses as to when, and over which sites, we would find this interaction, an ERP interaction would provide the first evidence that self-relevance and valence are not processed independently in the brain.

Chapter 2: METHODS

2.1 Online Sentence Validation Study

2.1.1 Participants

Ninety [90] University of Waterloo undergraduates participated in this online study. After excluding those who did not respond to more than 25 of the 156 questions, the final sample included 68 participants (36 female, *M* = 20.72 years of age, *SD* = 1.52), with 33 (18 female) randomly assigned to the male pronoun group and 35 to the female pronoun group (18 female) – see below. The study was approved by the university Research Ethics Board, and participants received course credit for their time.

2.1.2 Sentence Construction

Sentences were constructed to later prime the face stimuli in the EEG-Eye tracking study, providing the context under which faces would be viewed. All sentences were six words long, and varied in valence (positive and negative) and self-relevance (referring to the participant – self-relevant, or to someone else –other-relevant). When they referred to a male having an other-relevant opinion, the pronouns ‘her’ or “she” were always used mid-sentence so that it was clear that the individual was expressing an opinion of someone else, and not of himself (e.g., “He thinks she looks really refreshed.”). The equivalent was done for sentences referring to a female having an other-relevant opinion (e.g., “She thinks he looks really refreshed.”). Self-relevant sentences were created by exchanging the pronouns ‘his/her’ and ‘she/he’ for ‘your’ or ‘you’ (e.g., a change from “She thinks he looks really refreshed” to “She thinks you look really refreshed” and from “She thinks his eyes are pretty” to “She thinks your eyes are pretty”). Valence was manipulated by exchanging the key descriptors in the sentence with positive or negative words describing a similar construct (e.g., “look really refreshed/sweaty”, “are really boring/interesting”).

Although this was not the goal of the current experiment, the intention was to create sentences which could later be used in an investigation of how individual differences in social anxiety impact the contextual modulation of face perception. Thus, the sentences were designed to target three categories of core fears heightened in those with high social anxiety, including one’s social competency, physical appearance, and behavioural displays which signal to others that an individual is anxious (Moscovitch, 2009; Moscovitch et al., 2013). *Social competence* sentences had descriptors which referenced an individual’s personality traits or social skills (e.g., using descriptors like “really intelligent”, “very antisocial”). *Physical attractiveness* sentences had descriptors which referred to physical traits (e.g., “eyes are pretty”, “smell bad”). *Signs of anxiety* sentences had descriptors referring to behaviours or visual cues of nervousness (e.g., “look really sweaty”, “are panicking”). Sentences were adapted from key words described by Moscovitch (2009), and structured similarly as the sentences used by Weiser et al. (2014).

Thirteen descriptors were created for each of the three core categories, with self-relevant positive, self-relevant negative, other-relevant positive and other-relevant negative variations of each (Table 1; e.g., “He/she thinks you are socially adept.”, “He/she thinks you are socially awkward.”, “He/she thinks she/he is socially adept.”, “He/she thinks she/he is socially awkward.”). This resulted in 52 sentences for each core category, for a total of 156 sentences.

2.1.2 Study Design and data analysis

Participants were randomly assigned to one of two study versions. In version one, all 156 sentences began with male pronouns, referring to a male having opinions of the participant and others. In version two, all sentences began with female pronouns. This kept the study length under an hour, while ensuring that the gender of the individual expressing all the opinions would be consistent for each participant. In each version, the sentences were presented in random order.

Participants were asked to rate the valence of the emotion each sentence elicited by clicking a radial button on a 9-point Likert scale. A rating of 1 (far left button) meant very negative and a rating of 9 (far right button) meant very positive. Participants were also asked to rate how exciting or stressful the emotion elicited was on a similar scale, where a rating of 1 meant not at all exciting or stressful (very unarousing) and a rating of 9 meant very exciting or stressful (very arousing). On average, each participant rated 154.18 (*SD* =4.30) sentences.

Data from the two study versions were combined for analysis. For each descriptor, participants were shown four sentences – a self-relevant positive, self-relevant negative, other-relevant positive and other-relevant negative variation. First, the ratings of valence and arousal were averaged across participants for these four variations of each descriptor (Table 1). A valence by self-relevance "interaction" score was then calculated[1]. The eight descriptors with the largest interaction score in each category were chosen for the later EEG-eye tracking study (bolded in Table 1) and were analyzed statistically as described below. This was done to maximize the chances of finding a valence by self-relevance interaction at the ERP level.

For each participant, average *arousal ratings* obtained across the 28 selected descriptors (bold in Table 1, regardless of category) were calculated for the self-relevant positive, self-relevant negative, other-relevant positive and other-relevant negative variations. These ratings were then entered into a repeated measures Analysis of Variance (ANOVA) with the within-subject factors of self-relevance (2; self, other) and sentence valence (2; positive, negative). Similarly, the average *valence ratings* were calculated for each participant and for the four

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[1] Taken by subtracting the self-other positive difference from the self-other negative difference for valence ratings. The larger this score, the stronger the "interaction" between valence and self-relevance for that descriptor.

conditions and were analysed using a 2 (self-relevance; self, other) by 2 (sentence valence; positive, negative) repeated measures ANOVA.

Table 1. Sentence validation results, with mean valence and arousal ratings (*SE* in parentheses) obtained across all 68 participants as a function of descriptor valence and self-relevance. Bolded sentences were later used in the EEG-Eye tracking experiment.

SOCIAL COMPETENCE

Descriptors	Self Positive Valence	Self Negative Valence	Other Positive Valence	Other Negative Valence	Self Positive Arousal	Self Negative Arousal	Other Positive Arousal	Other Negative Arousal	Valence X Self-relevance Score
socially awkward /socially adept	6.36(1.67)	2.66(1.47)	5.66(1.80)	3.30(1.61)	5.50(1.93)	4.64(2.66)	4.67(2.03)	3.84(2.26)	**1.34**
no personality/great personality	7.84(1.38)	1.98(1.42)	6.83(1.95)	2.88(2.01)	6.57(2.01)	4.99(2.92)	5.79(2.32)	4.17(2.53)	**1.91**
jokes are humorless /hilarious	7.53(1.45)	2.79(1.70)	6.88(1.89)	3.25(1.53)	6.57(1.93)	4.35(2.65)	6.88(2.38)	4.13(2.18)	1.12
very shy/confident	7.44(1.52)	3.98(2.16)	7.03(1.53)	4.52(1.60)	6.39(2.04)	4.68(2.16)	5.81(2.34)	4.36(2.18)	0.95
very friendly /unfriendly	7.71(1.23)	1.97(1.40)	7.78(1.68)	2.88(1.98)	7.71(1.68)	5.14(2.94)	5.34(2.12)	4.24(2.59)	0.85
really intelligent /unintelligent	7.95(1.41)	2.13(1.69)	7.22(1.93)	3.03(2.10)	6.62(2.01)	5.17(3.07)	5.82(2.37)	4.32(2.63)	**1.62**
really want/never want to date	7.21(1.82)	2.80(1.88)	6.93(2.05)	3.04(2.02)	6.58(2.07)	4.52(2.88)	6.15(2.47)	4.27(2.67)	0.53
really boring/ interesting	7.84(1.36)	1.97(1.40)	6.90(1.95)	2.88(1.98)	6.58(1.98)	5.14(2.94)	5.80(2.32)	4.24(2.59)	**1.27**
always enjoys/dreads meeting with	7.73(1.19)	2.34(1.79)	6.82(2.04)	2.87(1.90)	6.50(2.02)	5.00(3.04)	5.70(2.22)	4.23(2.66)	**1.45**
lack/have charisma	7.09(1.58)	2.86(1.61)	6.52(1.85)	3.51(1.56)	6.08(2.00)	4.91(2.34)	5.47(2.28)	4.07(1.96)	**1.22**
very sociable/ antisocial	7.28(1.41)	2.68(1.60)	6.74(1.49)	3.37(1.82)	6.00(2.07)	4.92(2.54)	5.22(2.33)	4.17(2.50)	**1.22**
emotionally stunted/mature	7.03(1.39)	2.85(1.45)	6.72(1.81)	3.57(1.65)	5.57(2.17)	4.68(2.37)	5.00(2.13)	4.40(2.17)	1.04
express yourself well/poorly	7.19(1.39)	2.92(1.68)	6.68(1.49)	3.54(1.69)	5.65(2.03)	4.85(2.69)	5.06(2.04)	3.90(2.10)	**1.13**

PHYSICAL ATTRACTIVENESS

Descriptors	Self Positive Valence	Self Negative Valence	Other Positive Valence	Other Negative Valence	Self Positive Arousal	Self Negative Arousal	Other Positive Arousal	Other Negative Arousal	Valence X Self-relevance Score
face is lovely/ugly	7.67(1.50)	1.88(1.39)	6.88(1.83)	2.77(2.05)	6.39(2.14)	5.39(3.01)	5.45(2.25)	4.89(2.78)	**1.68**
attractive/unattractive	7.52(1.55)	2.56(1.69)	6.80(2.00)	3.18(1.69)	6.46(2.11)	4.76(2.62)	5.78(2.50)	4.31(2.50)	**1.34**
an unhealthy/healthy weight	6.74(1.65)	2.77(1.67)	6.51(1.65)	3.27(1.84)	5.33(2.11)	4.74(2.52)	4.77(2.27)	4.14(2.40)	0.73
hair is healthy/greasy	7.03(1.64)	2.67(1.56)	6.55(1.67)	3.97(2.37)	5.36(2.26)	4.85(2.68)	4.66(2.40)	3.97(2.37)	**1.78**
smell really good/bad	7.23(1.64)	1.84(1.23)	6.91(1.76)	2.68(2.03)	6.18(2.08)	5.24(3.12)	6.01(2.41)	4.59(2.81)	**1.16**
look really exhausted/well-rested	6.31(1.45)	3.84(1.41)	6.27(1.52)	4.20(1.57)	4.84(2.15)	4.14(2.08)	4.32(2.34)	4.01(2.10)	0.40
skin is blemished/flawless	7.49(1.55)	3.17(1.48)	7.28(1.73)	3.66(1.42)	6.23(2.13)	5.06(2.38)	5.71(2.43)	4.17(2.26)	0.70
look really weird/cool	7.40(1.36)	2.55(1.63)	6.86(1.79)	3.11(1.76)	6.15(2.17)	5.12(2.71)	5.77(2.27)	4.37(2.20)	**1.10**
look quite fit/fat	7.65(1.25)	2.44(1.63)	7.00(1.69)	2.70(1.72)	6.36(2.22)	5.02(2.96)	5.74(2.41)	4.32(2.56)	0.91
have great/gross hair	7.51(1.11)	2.32(1.53)	6.79(1.75)	2.60(1.62)	5.99(1.95)	4.75(2.69)	5.44(2.26)	4.23(2.47)	1.00
eyes are dull/pretty	7.58(1.49)	3.03(1.43)	6.98(2.01)	3.70(1.64)	6.06(2.13)	4.18(2.36)	5.45(2.33)	3.90(2.11)	**1.28**
look very neat/ sloppy	6.95(1.33)	2.48(1.43)	6.23(1.80)	3.14(1.80)	5.42(2.03)	4.70(2.64)	5.03(2.31)	3.96(2.20)	**1.38**
poorly dressed/well dressed	7.51(1.10)	2.76(1.65)	6.82(1.55)	3.17(1.72)	6.09(1.80)	4.77(2.52)	5.49(2.33)	4.15(2.39)	**1.10**

SIGNS OF ANXIETY

Descriptors	Self Positive Valence	Self Negative Valence	Other Positive Valence	Other Negative Valence	Self Positive Arousal	Self Negative Arousal	Other Positive Arousal	Other Negative Arousal	Valence X Self-relevance Score
speak very effortlessly/hesitantly	6.91(1.63)	3.80(1.71)	6.50(1.80)	4.04(1.42)	5.47(2.27)	4.23(2.13)	5.02(2.46)	4.01(2.16)	**0.65**
always/never fidget	5.46(1.34)	3.60(1.30)	5.50(1.28)	4.15(1.47)	3.80(2.23)	4.27(1.99)	4.08(1.98)	3.32(1.79)	0.50
sound very terrified/confident	7.42(1.55)	3.22(1.66)	7.01(1.65)	3.30(1.63)	6.30(2.18)	4.84(2.50)	5.63(2.41)	4.55(2.54)	0.50
voice is shaky/steady	6.65(1.30)	3.48(1.38)	6.10(1.59)	3.79(1.23)	4.89(1.99)	4.46(2.42)	4.89(1.99)	3.98(1.99)	**0.86**
words are mumbled/clear	6.69(1.26)	3.16(1.44)	5.97(1.75)	3.52(1.62)	4.98(1.89)	4.67(2.28)	4.25(2.00)	3.88(2.19)	**1.08**
always/never thinks you are blushing	5.02(1.41)	4.98(1.33)	4.98(1.33)	5.36(1.59)	4.23(2.27)	5.37(2.04)	4.04(2.17)	4.75(2.12)	0.41
look really refreshed/sweaty	6.78(1.28)	3.07(1.65)	6.23(1.77)	3.56(1.76)	5.32(2.03)	4.61(2.49)	4.85(2.30)	4.34(2.58)	**1.04**
quite anxious/relaxed	6.32(1.44)	3.67(1.63)	6.12(1.59)	3.82(1.41)	4.95(2.07)	4.50(2.26)	4.38(1.97)	4.49(2.19)	0.35
very tense/calm	6.95(1.33)	3.85(1.50)	6.14(1.48)	4.20(1.69)	5.05(2.31)	4.88(2.08)	4.26(2.15)	4.13(2.18)	**1.17**
avoiding/meeting gaze	5.80(1.55)	4.01(1.62)	5.65(1.51)	4.16(1.21)	4.96(2.11)	4.66(2.10)	5.08(2.20)	4.01(2.02)	0.31
look really emotional/composed	7.01(1.28)	4.02(1.64)	6.42(1.37)	4.38(1.69)	5.67(1.90)	4.91(2.00)	4.89(2.20)	4.62(2.10)	**0.95**
eloquent/stuttering	6.83(1.76)	3.55(1.49)	6.44(2.02)	3.92(1.75)	5.59(2.05)	4.64(2.35)	4.97(2.30)	4.02(2.21)	**0.75**
panicking/unafraid	6.82(1.34)	3.17(1.48)	5.76(1.69)	3.74(1.59)	5.45(2.02)	4.97(2.42)	4.59(2.33)	4.41(2.22)	**1.63**

2.1.3 Results

Arousal ratings - There was a significant main effect of sentence valence (Figure 1a), $F(1,67) = 16.564$, $MSE = 4.231$, $p < .001$, $\eta_p^2 = .198$, with positive sentences rated as eliciting more arousing emotions ($M = 5.53$, $SD = .19$) than negative sentences ($M = 4.51$, $SD = .23$). As expected, there was also a main effect of self-relevance, $F(1,67) = 23.127$, $MSE = 1.307$ $p < .001$, $\eta_p^2 = .257$, with higher ratings in response to the self-relevant sentences ($M = 5.35$, $SD = .18$) than the other-relevant sentences ($M = 4.69$, $SD = .19$). There was no interaction between self-relevance and sentence valence on arousal ratings ($p = .924$).

V*alence ratings* - A significant main effect of sentence valence (Figure 1b), $F(1,67) = 302.694$, $MSE = 3.089$, $p < .001$, $\eta_p^2 = .819$, confirmed that sentences with positive descriptors elicited more positive emotions ($M = 6.88$, $SD = .11$) than those with negative descriptors ($M = 3.17$, $SD = .12$). There was no main effect of self-relevance, $F(1,67) = .181$, $MSE = .142$, $p = .672$, $\eta_p^2 = .003$, though as intended by the preselection of sentences, there was a strong valence by self-relevance interaction, $F(1,67) = 20.822$, $MSE = 1.490$, $p < .001$, $\eta_p^2 = .237$. A paired t-test, $t(67) = 3.795$, $p < .001$, confirmed that positive sentences were rated as eliciting more positive emotions when they referred to the participant ($M = 7.21$, $SD = .92$) compared to someone else ($M = 6.55$, $SD = 1.34$). Similarly, negative sentences that were self-relevant elicited more negative emotions, $t(67) = -5.163$, $p < .001$; $M = 2.82$, $SD = .11$, than negative sentences that were other-relevant ($M = 3.52$, $SD = 1.21$). In summary, the effect of descriptor valence was amplified when the descriptors were also self-relevant.

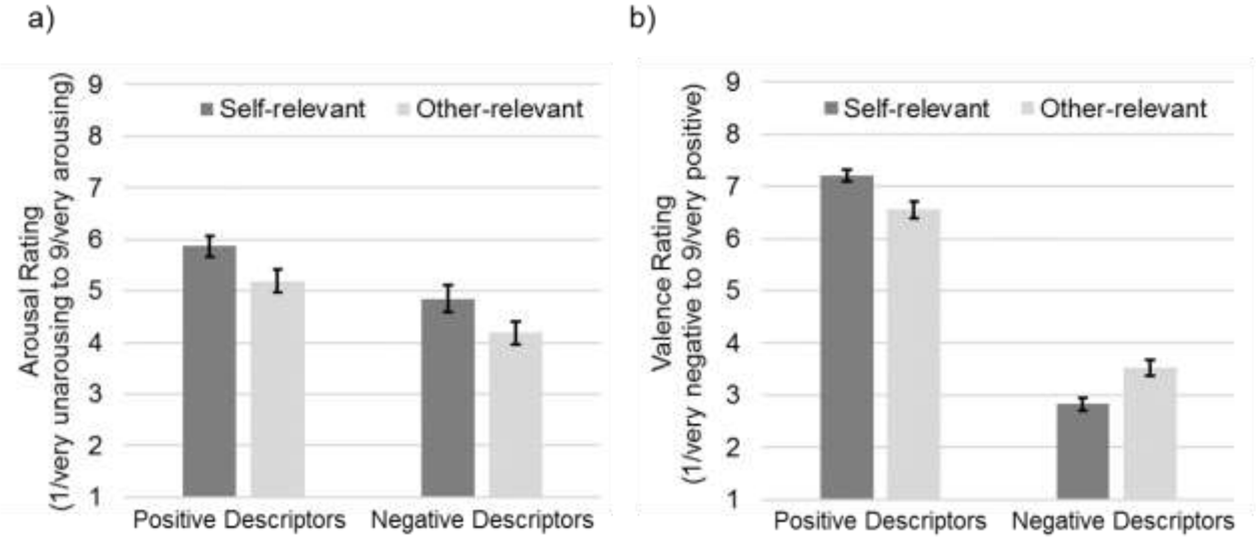

Figure 1. a) *Arousal* ratings obtained in the sentence validation study. **b)** *Valence* ratings obtained in the sentence validation study.

2.2 In-lab EEG-Eye tracking Study

2.2.1 Participants

None of the participants in EEG-eye tracking study took part in the online sentence validation study previously reported. Eligibility to participate was determined by a pre-screening questionnaire administered at the beginning of each term. Eligible individuals were between the age of 18-29, right-handed, and reported normal or corrected-to-normal vision. They reported no history of psychiatric or neurological illness, no past loss of consciousness spanning more than 5 minutes, and no psychiatric or recreational drug use. To ensure both English proficiency and a uniform cultural exposure, only those who had lived in Canada or the United States for the past 5 years were eligible. Individuals were also asked to rate their ability to recognize individuals and facial expressions on Likert-type scales with radial buttons ranging from 0 (extremely poor) to 10 (extremely good). Ratings of 7 or higher were considered sufficient to ensure that the individual had no face-related impairments. Ninety [90] eligible undergraduates came into the lab to participate. They gave written informed consent at the study onset and received both course credit and $5.00 upon completion. This study was approved by the University of Waterloo Research Ethics Board.

Before the data analysis stage, 7 participants were excluded because they failed to complete the eye-tracking calibration, 4 because electrode impedances could not be lowered to an acceptable level, 1 because we did not have a cap of the appropriate size, 4 because the EEG or eye-tracking data did not save properly (data were lost), and 3 due to illness during or before the study. Of the 71 that were included in the data analysis stage, 9 were rejected because there were too few trials remaining after excluding trials with eye-movements during the first 250ms of face presentation (see method below). Finally, 6 were rejected because there were too few trials remaining after artifact rejection, leaving a final sample of 56 participants (27 female, *M* = 20.25 years of age, *SD* = 1.69).

2.2.2 Face Stimuli

Images from four male and four female identities were selected from the Radboud database (Langer et al., 2010) for the experimental blocks (identities 09, 10, 19, 30, 31, 32, 33, 61). Images from an additional male and female were used in the practice block (identities 26 and 71). For each identity, direct, averted left and averted right gaze images were selected, and cropped to display the head, neck, and upper shoulders with the GNU Image Manipulation Program (GIMP 2.8). All images had a neutral expression. To control for any asymmetry between the left and right sides of the stimuli, each image was flipped about the y-axis to create another image (e.g., the flipped averted left gaze image became a second averted right image). This resulted in two left, two right, and two direct gaze images for each identity (Figure 2).

Each image was presented on a white background in the centre of the monitor, subtending 10.64° horizontally and 15.08° vertically. In between trials, a fixation cross appeared 13.59° down on the horizontal midline, chosen so that participants' eyes would be fixated between the nasion and the nose when the face stimuli appeared.

We chose to use colour images for increased ecological validity. The SHINE package (Willenbockel, Sadr, Fiset, Horne, Gosselin, & Tanaka, 2010) was used to minimize the influence of low-level image features on ERPs elicited by the face. All pictures were converted to greyscale and equalized on mean pixel intensity (*M* = 0.61, *SD* = 0.0005) and root mean square (RMS) contrast (*M* = 0.45, *SD* = 0.0006). Custom matlab scripts were then used to add the colour information back into each image.

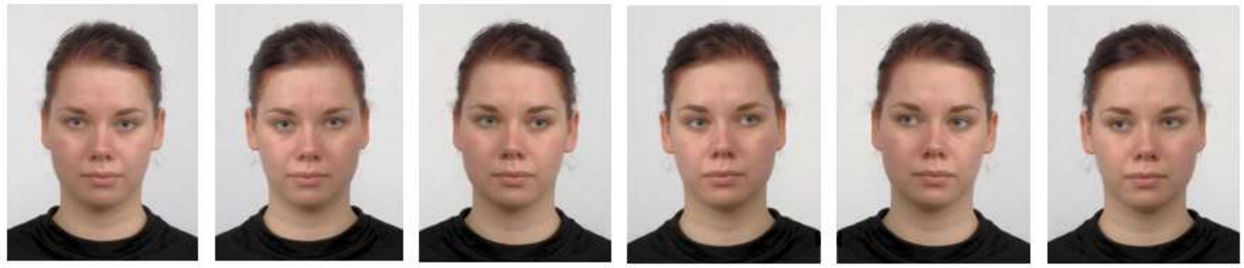

Figure 2. Sample stimuli for the direct, averted right and averted left gaze conditions and their mirror-reversed versions.

2.2.3 Experimental Design

After providing informed consent, participants completed a demographics questionnaire and were fitted with an EEG cap. The computer task took place in a dimly-lit, sound-attenuated Faraday cage. Screen resolution was set to 1600x1200, with an 85Hz refresh rate. An Eyelink 1000 eye-tracker tracked eye-movements at a sampling rate of 1000Hz. The Miles test (Miles, 1930) was used to determine each participant's dominant eye for tracking. A chinrest minimized head movement and maintained a constant distance of 65cm from the screen.

Participants were informed that they would be reading sentences expressing an individual's opinion of the participant or of someone else (Figure 3). They were asked to press the spacebar after reading, and then to fixate on the following fixation cross, which would trigger a picture of the person who had expressed the opinion they had just read. The importance of keeping their eyes as still as possible for the face screen, as well as for the blank screen which would appear after, was emphasized. They were told they could move their eyes again once a prompt appeared, asking them to use the number keys from 1-9 to rate how positive or negative the face made them feel. A rating of 1 corresponded to 'very negative' while a rating of 9 corresponded to 'very positive'. After responding, a second prompt would appear asking them to rate how affectively aroused the face made them feel using the number keys from 1-9, where a rating of 1 corresponded to 'very unaroused' and a rating of 9 corresponded to 'very aroused'. Affective arousal was defined for the participant as a feeling of excitement or stress and explained further until they correctly understood the meaning. Participants completed a minimum of four practice trials to ensure that they were comfortable with the task.

Each trial began with the sentence screen. When participants pressed the space bar, the trial advanced to the fixation cross screen. Participants had to maintain fixation on the cross (which appeared between the nasion and the nose) for 300ms within a region of interest of 0.98° x 0.98° to trigger the next screen with the face stimulus. If the trigger requirements were not met within 10 seconds, a drift correct occurred, cancelling that trial. Eye-tracking re-calibrations were performed when necessary. The face remained on the screen for 500ms, followed immediately by a 300ms blank screen. The valence rating screen then appeared and remained until the participant responded by pressing a number key from 1 to 9. The arousal rating screen then appeared, again remaining until the participant pressed a number key.

Contextual sentences were chosen from the online sentence validation study (see section 2.3, bolded descriptors in Table 1) and varied in self-relevance (referring either to the participant or to someone else) and valence (positive or negative). The face stimuli had either direct or averted gaze. There were an equal number of direct and averted gaze trials, with half of the averted gaze trials consisting of faces looking to the left and half to the right (grouped together for analysis). Thus, there were a total of eight conditions (2 self-relevance x 2 valence x 2 gaze directions), all tested in a within-subjects design.

The study was programmed using SR Research's Experiment Builder 1.10.1385 and consisted of 8 blocks with 96 trials each. There were 12 trials per each of the 8 conditions in each block, presented randomly, and 96 trials per condition over the course of the experiment. Throughout the experiment, the same identities were always associated with either positive or negative statements, with each one referring an equal number of times to the participant as to someone else. Half of the identities (4) appeared in each block, with one male and one female assigned to the positive valence condition, and the other male and female assigned to the negative condition. Six different versions of the experiment were created to ensure that the identities paired with positive or negative statements were counterbalanced across participants.

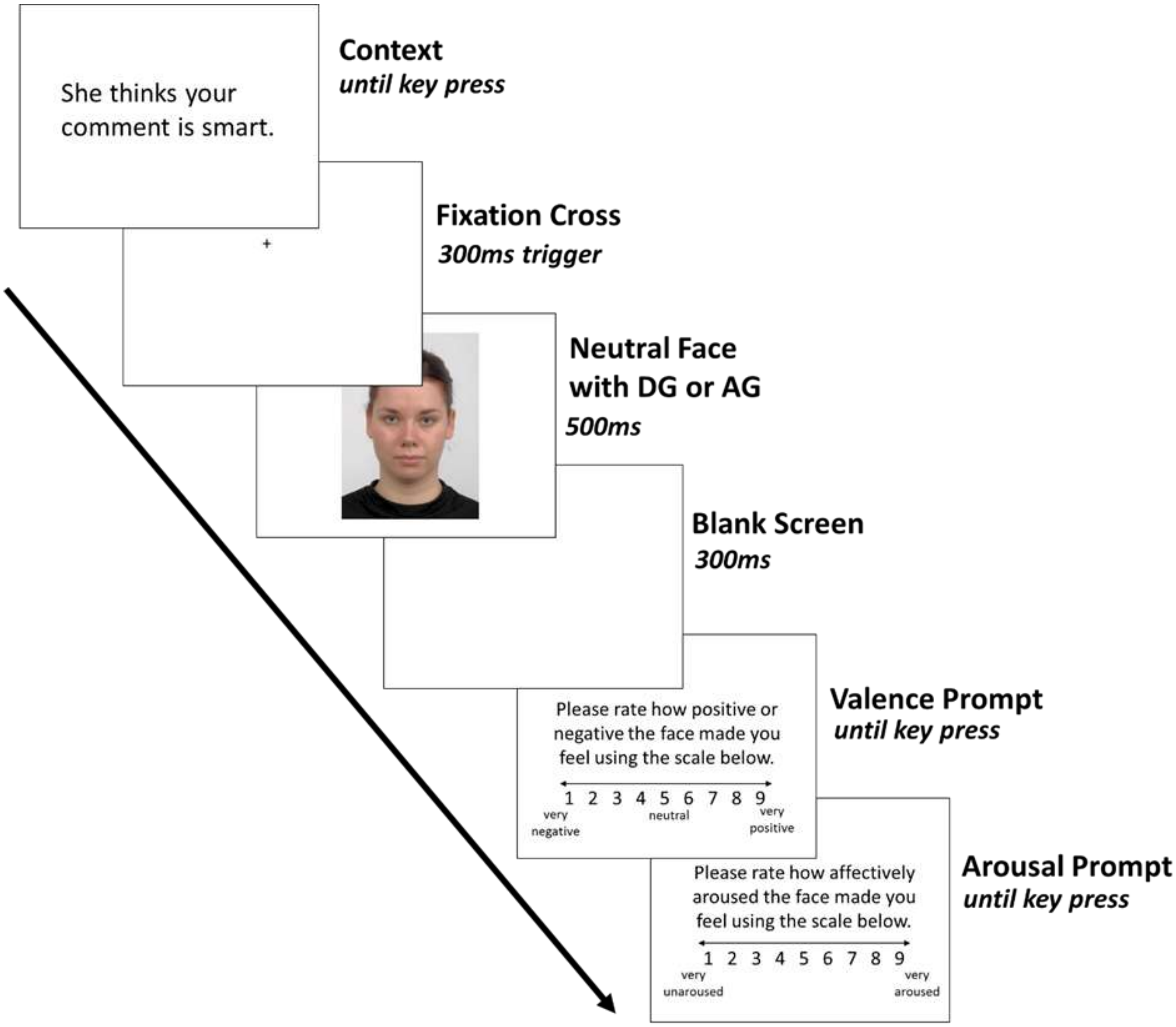

Figure 3. Sample progression for a positive self-relevant trial. ERPs were time-locked to the onset of the face stimulus.

2.2.4 Electroencephalography recording and pre-processing

An Active-two Biosemi system with 72 channels was used for EEG recordings. Caps had 66 channels under the extended 10/20 system including two posterior electrodes to help pick up activity elicited by face-presentation (PO9 and PO10). One electrode was also placed on the outer canthus of each eye, one over each infra-orbital ridge, and one over each mastoid. Data were collected at a 512Hz sampling rate, with a Common Mode Sense (CMS) active-electrode and a Driven Right Leg (DRL) passive-electrode as the ground[2]. Electrode "impedances" were kept within a ±20μV[3] range, whenever possible.

Eye-tracking interest area reports were created for the sentence screen, with a rectangular region of interest (ROI) that covered the text (subtending 22.35^{o} horizontally and 2.24^{o} vertically, positioned $18.18\,^{o}$ down and centered horizontally). Trials where participants made less than 2 fixations in this region (ie. the sentence was not read) were excluded, resulting in an average of 13.02 (*SD* = 34.29) trials removed per participant. Interest area reports were also used to ensure that participants did not make eye-movements during the N170 ERP component time window following face presentation, as this component has been shown to display sensitivity to fixation location on the face (de Lissa et al., 2014; Nemrodov, Anderson, Preston & Itier, 2014; Neath & Itier, 2015; Neath-Tavares & Itier, 2016). Trials in which participants fixated outside of a circular 1.57^{o} ROI (a small region situated between the nasion and the nose, which did not include the eyes or eyebrows) within the first 250ms after face onset were removed. This resulted in an average of 19.44 (*SD*=11.07) trials per condition removed per participant at this stage.

The EEGLab (Derlome & Makeig, 2004) and ERPLab (http://erpinfo.org/erplab) toolboxes in MATLAB were used to process the data. An average-reference was computed

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[2] Please note that the Biosemi Active-Two system does not use an actual recording reference site like other classic systems.

[3] Also note that the ActiveTwo system does not use actual impedances in KΩ as other systems like Neuroscan.

offline and trials were epoched from -100ms pre- to 800ms post-face presentation using the 100ms pre-stimulus as baseline. Data were band-pass filtered between 0.01Hz and 30Hz.

Any channels excluding frontal and ocular electrodes (Fp1, Fpz, Fp2, AF3, AFz, AF4, AF8, AF7, IO1, IO2, LO1, and LO2) that were consistently noisy were first removed (to be interpolated later on). Trials with artifacts exceeding ±70μV on all remaining (non-frontal and non-ocular) channels were then excluded. Frontal and ocular channels were not included in these steps because they picked up eye-movements very clearly and our long epoch meant that most participants were unable to keep their eyes still for the whole trial (most trials would be removed during these steps if the frontal electrodes were included).

Independent Component Analysis (ICA) decomposition was then run on all channels using the ICA “runica” function in EEGLab (Delorme & Makeig, 2004). Components reflecting eye-blinks and lateral eye movements were removed for each participant. Any channels that had previously been removed were then added back in and interpolated. Finally, ERPs were created for each participant and condition and were visually inspected. A second manual cleaning stage was performed if the waveforms were deemed too noisy. At the end of the preprocessing stage, participants’ ERP waveforms included an average of 52.38 (*SD* =15.85) trials per condition. A repeated measures Analyses of Variance (ANOVA) run on the final number of trials per condition ensured that no conditions had a disproportionate number of trials compared to the others, $F(5.00,275.10) = .914$, $MSE = 32.027$, $p = .496$, $\eta_p^2 = .016$.

2.2.5 Data Analysis

For each participant, self-reported valence and arousal ratings were averaged to create a mean valence and arousal rating per condition. This was done after excluding trials where participants did not read the sentences, but included trials that were later removed from the EEG analyses due to eye-movements or electrode noise. Thus, while the majority of trials are included in both the behavioural and EEG analyses, the EEG analyses are performed on a subset of the data included in the behavioural analyses.

For the N170 analyses, each participant's ERP waveforms were examined individually. The right and left electrodes where the N170 was maximal were selected for each person and the amplitude and latency information were extracted for these electrodes between 115 and 225ms. The data were visually inspected to make sure that this range captured the N170 correctly for each participant. For the left hemisphere, 38 participants had their maximal N170 at P9, 4 at O1, 8 at PO9, 4 at PO7 and 2 at TP9. For the right hemisphere, 37 participants had their maximal N170 at P10, 8 at PO10, 4 at O2, 5 at PO8, 1 at TP10, and 1 at P8.

A series of mean amplitude analyses were also performed across six 100ms time windows ranging from 150-250ms, 250-350ms, 350-450ms, 450-550ms, 550-650ms, and 650-750ms. Based on visual inspection, these analyses were run over four occipitotemporal sites on each hemisphere (P9/P10, PO9/PO10, TP9/TP10, and O1/O2), and over frontocentral and centroparietal sites, averaged during each time window to create left (C1, C3, CP1 and FC1) midline (CPz, Cz and FCz) and right (C2, C4, CP2 and FC2) electrode clusters.

SPSS Statistics 22 was used for all statistical analyses. Behavioural responses, N170 latency, N170 amplitude and the mean amplitude data were analyzed using repeated measures Analyses of Variance (ANOVAs). Significant hemisphere interactions were broken down with separate ANOVAs over the right and left hemispheres. When Mauchly's Test of sphericity was significant, the Greenhouse-Geisser corrections to the degrees of freedom were reported.

Chapter 3: RESULTS

3.1 Behavioural Valence Ratings

A repeated measures ANOVA with factors of valence (2; positive, negative), self-relevance (2; self, other), and gaze direction (2; direct, averted) was performed on participants' average valence ratings (how positive or negative the faces made them feel, averaged across trials).

As seen in Figure 4, faces viewed within positive contexts made participants feel more positive than those in negative contexts (main effect of valence), $F(1,55) = 91.377$, $MSE=6.339$, $p <.001$, $\eta_p^2=.624$. There was also a main effect of self-relevance, $F(1,55) = 5.037$, $MSE=.105$, $p =.029$, $\eta_p^2=.084$, which was strongly modulated by an interaction with valence (self-relevance x valence), $\mathrm{F}(1,55) = 44.830$, $\mathrm{MSE}=.309$, $\mathrm{p} <.001$, $\eta\mathrm{p}^2=.449$, just as valence ratings were in the sentence validation study. Within positive contexts (Figure 4a), faces placed in self-relevant contexts elicited more positive responses than faces placed in other-relevant contexts, $F(1,55) =21.795$, $MSE=.206$, $p <.001$, $\eta_p^2=.284$. Similarly, within negative contexts (Figure 4b), faces placed in self-relevant contexts elicited more negative responses than faces placed in other-relevant contexts, $F(1,55) =47.561$, $MSE=.208$, $p <.001$, $\eta_p^2=.464$.

Participants also reported that, overall, faces with direct gaze made them feel more positive than those with averted gaze (main effect of gaze direction), $F(1,55) = 18.079$, $MSE=.068$, $p <.001$, $\eta_p^2=.247$. However, this effect was qualified by two-way self-relevance by gaze, $F(1,55) = 6.295$, $MSE=.045$, $p =.015$, $\eta_p^2=.103$, and valence by gaze, $F(1,55) = 20.833$, $MSE=.050$, $p <.001$, $\eta_p^2=.275$ interactions, and a three-way valence by self-relevance by gaze direction interaction, $F(1,55) = 10.936$, $MSE=.062$, $p =.002$, $\eta_p^2=.166$. The three-way interaction was driven by an effect of gaze seen only in the self-relevant positive trials (Figure 4a) as indicated by a self-relevance by gaze interaction seen for positive, F (1,55) = 11.905, MSE=.077, p =.001, η_p^2=.178, but not negative, F (1,55) = 1.429, MSE=.030, p =.237, η_p^2=.025, trials. Bonferroni-corrected paired comparisons for positive self-relevant trials confirmed that faces with direct gaze elicited more positive ratings than faces with averted gaze, $t(55) = 5.609$, $p < .001$, $SE = .059$, while no gaze effect was seen for positive other-relevant trials, $t(55) = 1.749$, $p = .086$, $SE = .042$.

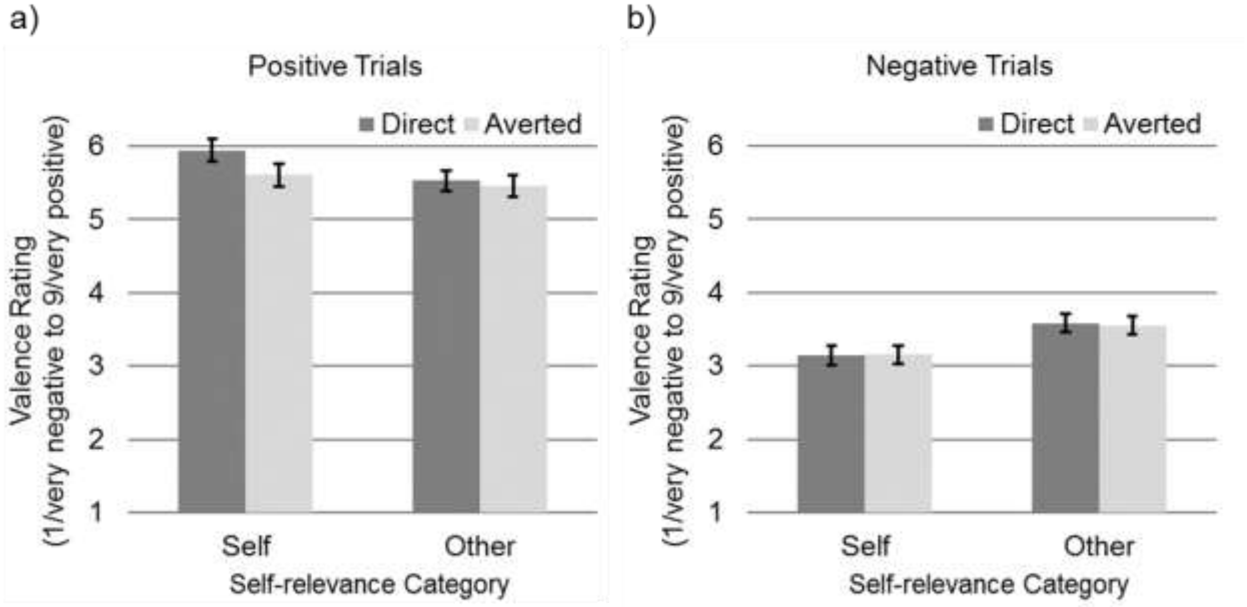

Figure 4. Valence ratings showing the self-relevance by gaze direction interaction for **a)** positive and **b)** negative trials.

3.2 Behavioural Arousal Ratings

An ANOVA with the factors of valence (2: positive, negative), self-relevance (2; self, other), and gaze direction (2; direct, averted) was performed on participants' ratings of how affectively aroused the faces made them feel.

As predicted, there was a main effect of self-relevance, $F(1,55) = 50.320$, MSE=1.059, $p <.001$, $\eta_p{}^2=.478$, with larger self-reported arousal in response to faces viewed under self-relevant contexts than under other-relevant contexts (Figure 5a). Participants also reported feeling more affectively aroused during trials where faces had direct gaze than averted gaze (main effect of gaze direction), $F(1,55) = 22.971$, MSE=.159, $p <.001$, $\eta_p{}^2=.295$. While the effect of gaze direction was significant for both self-relevant, $F(1,55) = 20.919$, MSE=.156, $p <.001$, $\eta_p{}^2=.276$, and other-relevant, $F(1,55) = 11.620$, MSE=.069, $p =.001$, $\eta_p{}^2=.174$, trials, a self-relevance by gaze direction interaction, $F(1,55) = 6.319$, MSE=.066, $p =.015$, $\eta_p{}^2=.103$, indicated that there was a larger effect of gaze direction for self-relevant trials than for other-relevant trials (Figure 5a). Similarly, while the gaze effect was present for both positive, $F(1,55) = 27.763$, MSE=.107, $p <.001$, $\eta_p{}^2=.335$, and negative, $F(1,55) = 8.737$, MSE=.110, $p =.005$, $\eta_p{}^2=.137$, trials, a valence by gaze direction interaction, $F(1,55) = 4.754$, MSE=.058, $p =.034$, $\eta_p{}^2=.080$, indicated that the gaze effect was slightly larger for positive trials (Figure 5b).

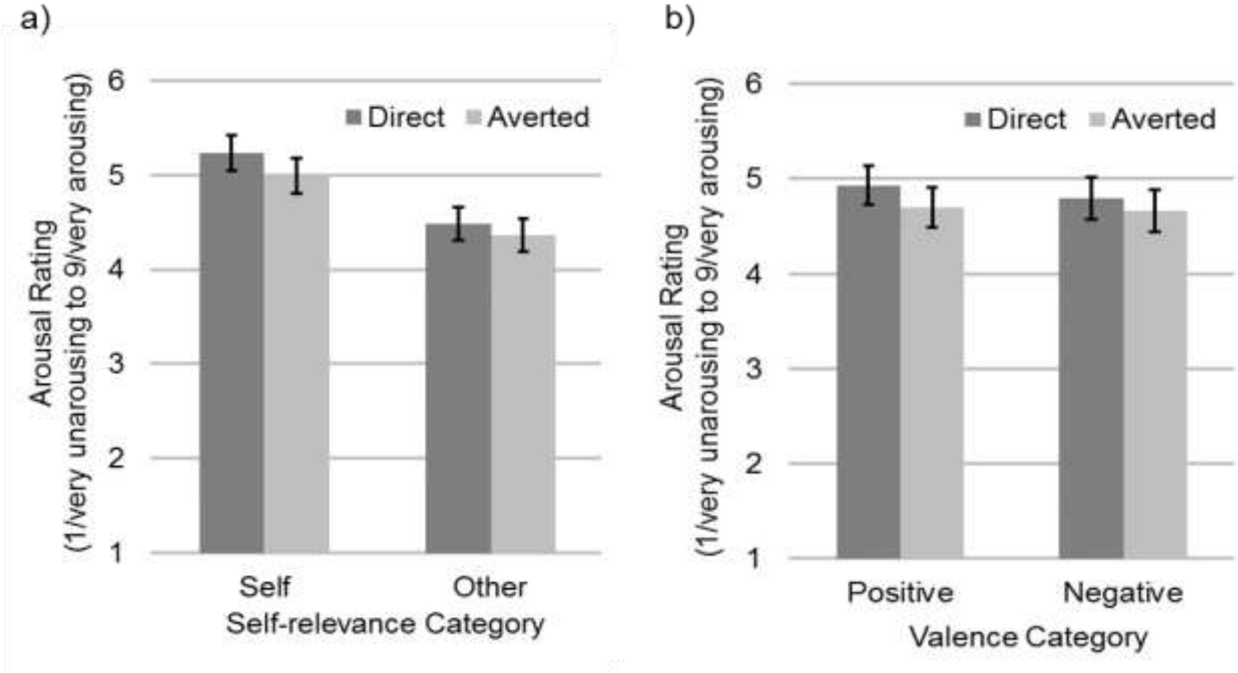

Figure 5. Arousal ratings. **a)** Self-relevance by gaze direction interaction for ratings of how affectively aroused the faces made participants feel. **b)** Valence by gaze direction interaction for ratings of how affectively aroused the faces made participants feel.

3.3 N170 Peak Amplitude Analysis

As there were no significant N170 latency effects, we focus below on only the N170 amplitude analyses. A hemisphere (2; left, right) by valence (2; positive, negative) by self-relevance (2; self, other) by gaze direction (2; direct, averted) repeated measures ANOVA was performed on the N170 amplitude data.

Overall, amplitudes were more negative over the right than the left hemisphere (Figure 6; main effect of hemisphere), $F(1, 55) = 4.290$, $MSE = 44.238$, $p = .043$, $\eta_p^2 = .072$. There was a trending main effect of self-relevance, $F(1, 55) = 3.510$, $MSE = 2.233$, $p = .066$, $\eta_p^2 = .060$, qualified by a trending self-relevance by hemisphere interaction, $F(1, 55) = 3.914$, $MSE = .966$, $p = .053$, $\eta_p^2 = .066$.

There was a significant three-way hemisphere by valence by gaze direction interaction in the omnibus ANOVA, $F(1, 55) = 7.585$, $MSE = 1.238$, $p = .008$, $\eta_p^2 = .121$. Separate ANOVAs over the right (Figure 6, top) and left (Figure 6, bottom) hemisphere indicated the valence by gaze direction interaction was significant in the right hemisphere (valence x gaze interaction in the RH), $F(1, 55) = 7.350$, $MSE = 1.335$, $p = .009$, $\eta_p^2 = .118$, but not the left, $F(1, 55) = .776$, $MSE = 1.860$, $p = .382$, $\eta_p^2 = .014$. As seen in Figure 6 (top), in the right hemisphere, the N170 was slightly larger for averted than direct gaze faces for the positive trials (effect of gaze for positive trials), $F(1, 55) = 5.772$, $MSE = 1.144$, $p = .020$, $\eta_p^2 = .095$, but not for negative trials, $F(1, 55) = 1.498$, $MSE = 2.309$, $p = .226$, $\eta_p^2 = .027$.

Finally, there was a significant three-way valence by self-relevance by gaze direction interaction in the omnibus ANOVA, $F(1, 55) = 16.766$, $MSE = 1.512$, $p < .001$, $\eta_p^2 = .234$. Separate ANOVAs for positive (Figure 7, top) and negative (Figure 7, bottom) trials indicated a significant interaction between self-relevance and gaze direction for positive trials (positive self-relevance by gaze interaction), $F(1, 55) = 12.189$, $MSE = 1.592$, $p < .001$, $\eta_p^2 = .181$, but not negative trials, $F(1, 55) = 3.575$, $MSE = 2.062$, $p = .064$, $\eta_p^2 = .061$. As shown in Figure 7 (top), there was a main effect of gaze direction for positive self-relevant trials, $F(1, 55) = 8.476$, $MSE = 1.483$, $p < .005$, $\eta_p^2 = .134$, with a larger N170 amplitude elicited by faces with averted than with direct gaze. In contrast, there was no effect of gaze direction for positive other-relevant trials, $F(1, 55) = 3.322$, $MSE = 2.170$, $p = .074$, $\eta_p^2 = .057$.

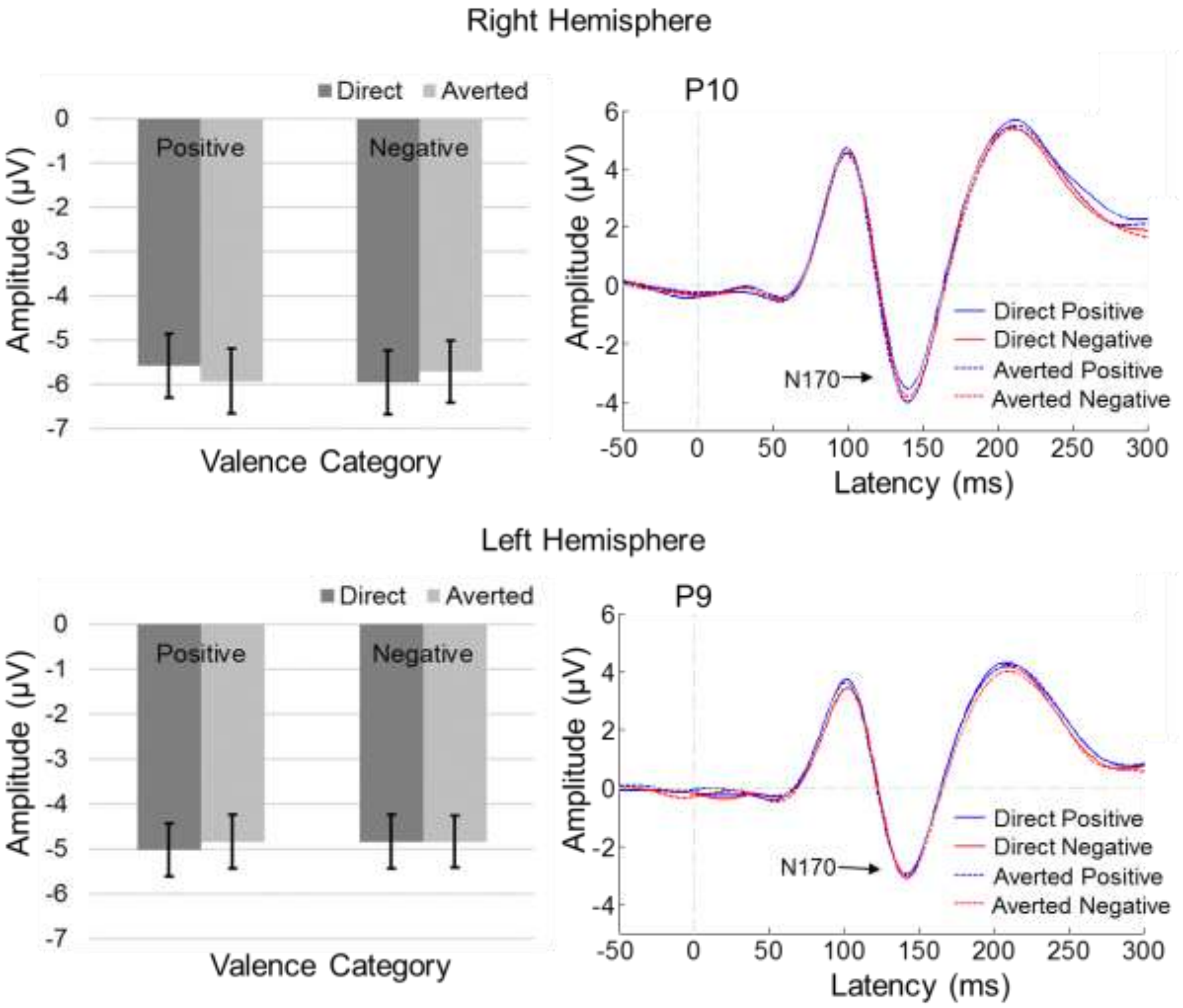

Figure 6. N170 amplitudes over the right (top panels) and left (bottom panels) hemisphere, averaged from each participant's peak electrode. Left panels display the mean N170 amplitude for direct and averted gaze faces as a function of contextual valence. Right panels display the N170 over a representative electrode (P9 and P10) for these conditions.

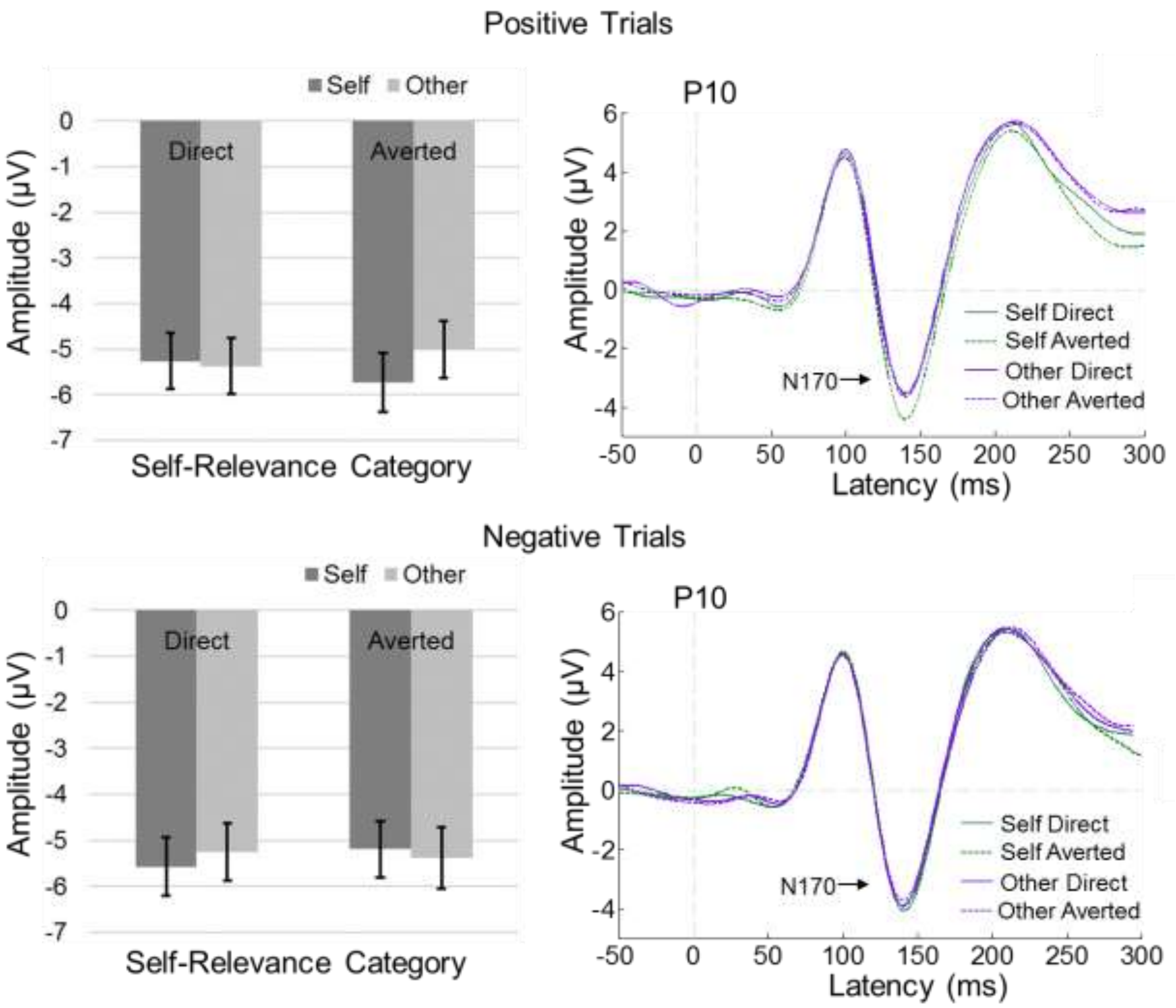

Figure 7. N170 amplitudes elicited by faces primed with positive (top panels) and negative (bottom panels) contexts. Left panels display the mean N170 amplitude for direct and averted gaze faces as a function of contextual self-relevance, averaged from the peak electrode of each participant. Right panels display the N170 for these conditions over a representative electrode (P9 and P10).

3.4 Mean Amplitude Analyses over Occipitotemporal Electrodes

A hemisphere (2; left, right) by electrode location (4; P9/P10, PO9/PO10, TP9/TP10, O1/O2), by valence (2; positive, negative) by self-relevance (2; self, other) by gaze direction (2; direct, averted) ANOVA was run on the mean amplitude for each 100ms time window (increments from 150 to 750ms).

There was a main effect of electrode location in all time windows (Table 2a), with O1/O2 sites producing the most positive amplitude, followed by PO9/PO10, P9/P10, and TP9/TP10 respectively, which all differed from each other. There were also significant main effects of hemisphere (Table 2b), across most time windows. From 250-450ms, the right hemisphere produced more positive amplitudes than the left. The pattern then reversed, with no significant hemisphere difference from 450-550ms, and finally more positive amplitudes over the left hemisphere from 550-750ms.

As shown in Figure 8(a), there was a main effect of valence between 250-350ms (Table 2c), with faces put into positive contexts producing a more positive amplitude than those put into negative contexts. There was also a consistent main effect of self-relevance (Table 2d), beginning during the 250-350ms window and persisting for all later time windows, with a more negative amplitude for the self-relevant than other-relevant trials. Hemisphere by self-relevance interactions (Table 2e) indicated that the effect of self-relevance was more pronounced in the right than in the left hemisphere between 250-350ms and then was uniquely right-lateralized in all later windows (Figure 9a, bottom left and right panels show sample occipitotemporal sites). There were also hemisphere by electrode location by self-relevance interactions (Table 2f) from 250-450ms, caused by a weakly significant (250-350ms) and trending (350-450ms) self-relevance by electrode location interaction over the right hemisphere, but not the left. This was driven by a weaker self-relevance effect on the occipital electrode O1, which was not significant between 250-350ms.

There was a weak valence by self-relevance interaction (Table 2g) from 450-550ms (trending from 350-450ms). Separate ANOVAs for positive (Figure 8b, top two left panels) and negative trials (Figure 8b, top two right panels) indicated that this was due to an effect of self-relevance on positive trials only, with faces placed into self-relevant contexts eliciting more negative amplitudes than those in other-relevant contexts. This two-way interaction was qualified by a weak three-way valence by self-relevance by gaze direction interaction (Table 2h) as seen on the N170, which was significant from 450-550ms and 650-750ms (trending from 350-450 and 550-650ms), driven by a larger self-relevance by gaze direction interaction for positive trials than negative trials, though neither of these were significant at any time window.

Statistical Effects	150-250ms	250-350ms	350-450ms	450-550ms	550-650ms	650-750ms
2. a) Electrode Location	F (1.518, 83.478) = 98.217, MSE=184.227, p < .001, η_p^2=.641 (O1/O2 > CB1/CB2 > P9/P10 > TP10/TP9)	F (1.640, 90.176) = 106.304, MSE=187.257, p < .001, η_p^2=.659 (O1/O2 > CB1/CB2 > P9/P10 >TP10/TP9)	F (1.623, 89.297) = 109.646, MSE=179.528, p < .001, η_p^2=.666 (O1/O2 > CB1/CB2 > P9/P10 > TP10/TP9)	F (1.845, 101.452) = 101.886, MSE=145.356, p < .001, η_p^2=.649 (O1/O2 > CB1/CB2 > P9/P10 > TP10/TP9)	F (2.193,120.616) = 99.839, MSE=117.158, p < .001, η_p^2=.645) (O1/O2 > CB1/CB2 > P9/P10 > TP10/TP9)	F (2.256, 124.076) = 67.333, MSE=120.117, p < .001, η_p^2=.550 (O1/O2 > CB1/CB2 > P9/P10 > TP10/TP9)
2. b) Hemisphere	---	F (1,55) = 6.626, MSE=51.735, p = .013, η_p^2=.108 (RIGHT > LEFT)	F (1,55) = 6.634, MSE=50.715, p = .013, η_p^2=.108 (RIGHT > LEFT)	---	F (1,55) = 4.248, MSE=39.674, p =.044, η_p^2=.072 (LEFT > RIGHT)	F (1,55) = 23.255, MSE=40.006, p < .001, η_p^2=.297 (LEFT > RIGHT)
2. c) Valence	---	F (1,55) = 6.467, MSE=5.775, p = .023, η_p^2=.090 (POSITIVE > NEGATIVE)	---	---	---	---
2. d) Self-relevance	---	F (1,55) = 15.065, MSE=6.513, p < .001, η_p^2=.215 (OTHER > SELF)	F (1,55) = 6.458, MSE=10.273, p = .014, η_p^2=.105 (OTHER > SELF)	F (1,55) = 5.990, MSE=10.431, p = .018, η_p^2=.098 (OTHER > SELF)	F (1,55) = 6.747, MSE=11.858, p = .012, η_p^2=.109 (OTHER > SELF)	F (1.55) = 5.577, MSE=14.225, p = .023, η_p^2=.092 (OTHER > SELF)
2. e) Hemisphere by Self-relevance	---	F (1,55) = 5.720, MSE=1.836, p = .020, η_p^2=.094 **RIGHT self-relevance effect:** F (1,55) = 19.742, MSE=4.377, p <.001, η_p^2=.264 (OTHER > SELF) **LEFT self-relevance effect:** F (1,55) = 5.592, MSE=3.972, p = .022, η_p^2=.092 (OTHER > SELF)	F (1,55) = 4.184, MSE=2.071, p = .046, η_p^2=.071 **RIGHT self-relevance effect:** F (1,55) = 9.178, MSE=6.699, p =.004, η_p^2=.143 (OTHER > SELF) LEFT self-relevance effect: F (1,55) = 2.397, MSE=5.645, p = .127, η_p^2=.042	F (1,55) = 7.400, MSE=2.1518, p = .009, η_p^2=.119 **RIGHT self-relevance effect:** F (1,55) = 10.445, MSE=7.150, p =.002, η_p^2=.160 (OTHER > SELF) LEFT self-relevance effect: F (1,55) = 1.110, MSE=5.799, p = .297, η_p^2=.020	F (1,55) = 4.408, MSE=3.001, p = .040, ηp^2=.074 **RIGHT self-relevance effect:** F (1,55) = 9.515, MSE=8.319, p =.003, η_p^2=.147 (OTHER > SELF) LEFT self-relevance effect: F (1,55) = 2.154, MSE=6.540, p = .148, η_p^2=.038	F (1,55) = 3.689, MSE=3.693, p = .060, ηp^2=.063 **RIGHT self-relevance effect:** F (1,55) = 7.784, MSE=10.194, p =.007, η_p^2=.124 (OTHER > SELF) LEFT self-relevance effect: F (1,55) = 1.761, MSE=7.724, p = .190, η_p^2=.031
2. f) Hemisphere by Electrode location by Self-relevance	---	F(3,165) = 2.958, MSE=.829, p = .034, η_p^2=.051 **RIGHT electrode by self-relevance interaction:** F(3.165) = 2.753, MSE=1.405, p =.044, η_p^2=.048 **P10 self-relevance effect:** F(1,55) = 19.244, MSE=2.382, p <.001, η_p^2=.259	F(3,165) = 2.753, MSE=1.005, p = .044, η_p^2=.048 RIGHT electrode by self-relevance interaction: F(3,165) = 2.456, MSE=1.532, p =.065, η_p^2=.043 LEFT electrode by self-relevance interaction: F(2.505, 137.755) =1.954, MSE=1.457, p =.134, η_p^2=.034	---	---	---

		TP10 self-relevance effect: ***F*(1,55) = 7.063, *MSE*=1.503, *p* =.010, η_p^2=.114** O2 self-relevance effect: *F*(1,55) = 3.139, *MSE*=2.352, *p* =.082, η_p^2=.54 **CB2 self-relevance effect:** ***F*(1,55) = 14.505, *MSE*=2.356, *p* <.001, η_p^2=.209** ________________ LEFT electrode by self-relevance interaction: *F*(2.158,118.663) =1.678, *MSE*=1.171, *p* =.189, η_p^2=.030				
2. g) Valence by Self-relevance	---	---	*F* (1,55) = 3.810, *MSE*=4.644, *p* = .056, η_p^2=.065	*F* (1,55) = 4.538, *MSE*=5.543, *p* = .038, η_p^2=.076 POSITIVE self-relevance effect: *F* (1,55) = 9.796, *MSE*=8.520, *p* =.003, η_p^2=.151 ________________ NEGATIVE self-relevance effect: *F* (1,55) = .560, *MSE*=7.454, *p* =.458, η_p^2=.010	---	---
2. h) Valence by Self-relevance by Gaze	---	---	*F* (1,55) = 3.784, *MSE*=5.852, *p* = .057, η_p^2=.064	*F* (1,55) = 4.688, *MSE*=6.780, p = .035, η_p^2=.079 ________________ POSITIVE self-relevance X gaze: *F* (1,55) = 2.398 *MSE*=6.782, *p* =.127, η_p^2=.042 ________________ NEGATIVE self-relevance X gaze: *F* (1,55) = 2.120, *MSE*=7.324, *p* =.151, η_p^2=.037	*F* (1,55) = 3.965, *MSE*=7.570, *p* = .051, η_p^2=.067	*F* (1,55) = 4.681, *MSE*=7.335, *p* = .035, η_p^2=.078 ________________ POSITIVE self-relevance X gaze: *F* (1,55) = 3.391 *MSE*=7.331, *p* =.071, η_p^2=.058 ________________ NEGATIVE self-relevance X gaze: *F* (1,55) = 1.399, *MSE*=7.789, *p* =.242, η_p^2=.025

Table 2. Statistical effects from the mean amplitude analyses at occipitotemporal sites, organized by time window. The first F value in each box is the result from the omnibus ANOVA. Subsequent lines are for follow up ANOVAs split over the indicated factors, with significant follow-up tests bolded. The direction of significant paired comparisons or main effects are indicated with ">".

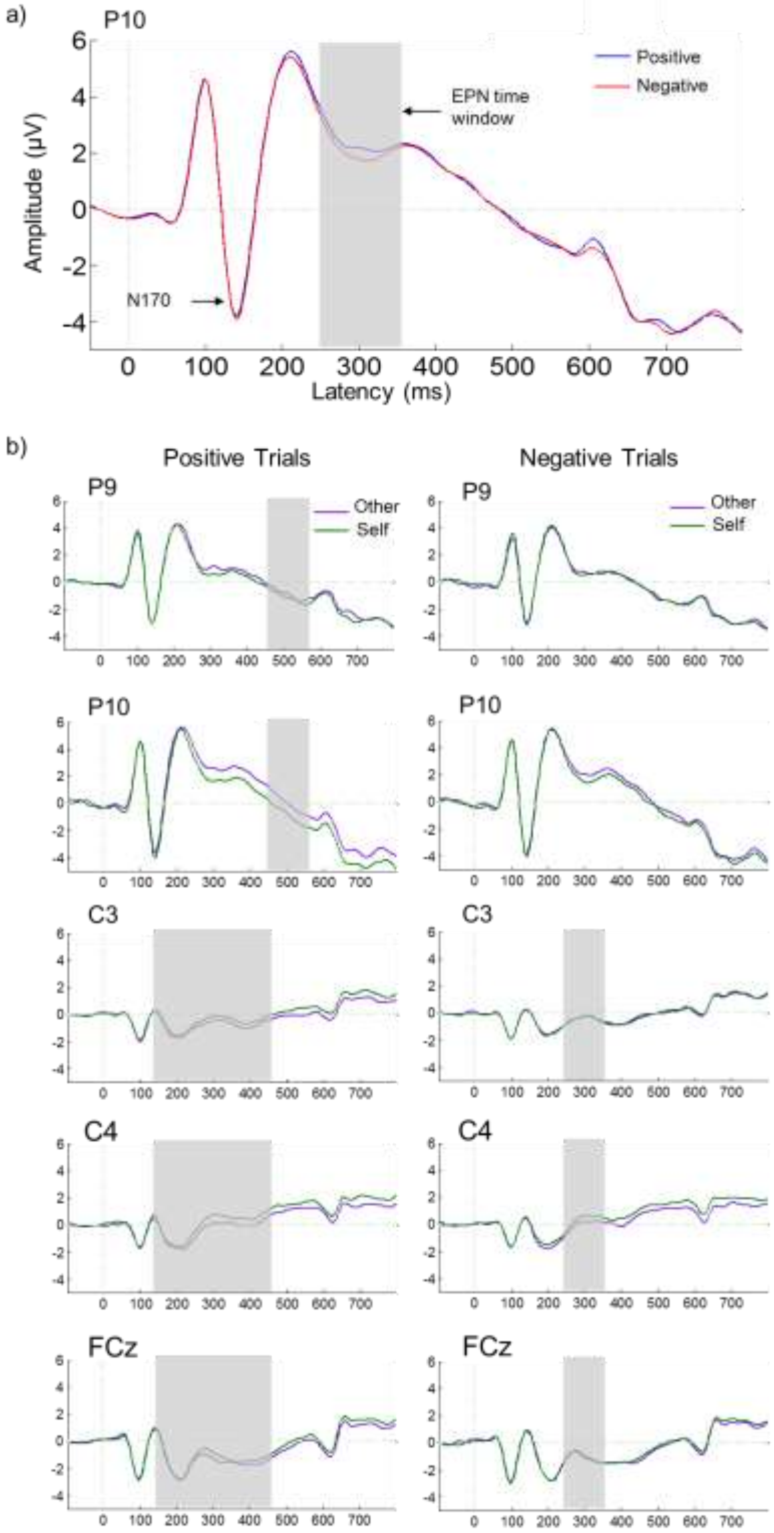

Figure 8. Significant time windows are outlined in grey. a) Main effect of contextual valence on ERP waveforms, shown on a representative occipitotemporal electrode. b) Valence and self-relevance interaction. ERP waveforms during positive (left panels) and negative (right panels) trials are shown for sample electrodes from left (P9) and right (P10) occipitotemporal sites, and left (C3), right (C4) and midline (FCz) centroparietal and frontocentral clusters.

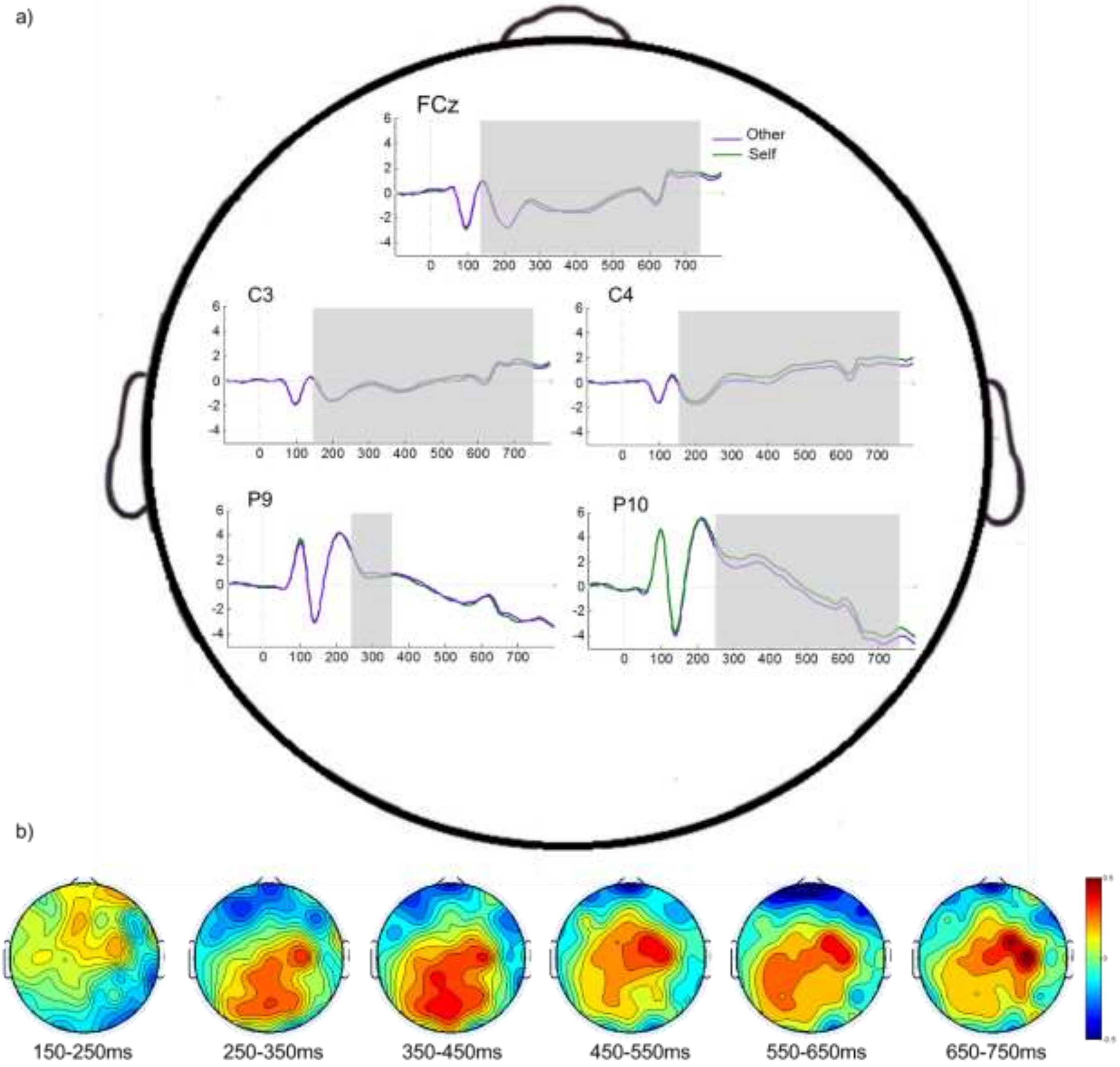

Figure 9. Main effect of self-relevance. **a)** Self-relevance effect shown over sample electrodes from left (P9) and right (P10) occipitotemporal sites, as well as from the left (C3), right (C4) and midline (FCz) clusters of centroparietal and frontocentral sites. Significant time windows are outlined in grey. **b)** Maps showing the mean voltage distribution of the grand average difference waveforms between other-relevant and self-relevant trials, in 100ms time intervals.

3.5 Mean Amplitude Analyses over Frontocentral and Centroparietal Electrodes

An electrode cluster (3; left: C1, C3, CP1 & FC1, midline: CPz, Cz & FCz, and right: C2, C4, CP2 & FC2) by valence (2; positive, negative) by self-relevance (2; self, other) by gaze direction (2; direct, averted) repeated measures ANOVA was then run on the mean amplitude for each time window (100ms increments from 150 to 750ms).

There was a main effect of electrode cluster from 250-750ms, with most positive amplitudes seen over the right cluster, followed by the midline and left clusters (Table 3a). There was also a main effect of self-relevance from 150ms-750ms (Table 3b), independent of electrode cluster. As seen in Figure 9, faces put into self-relevant contexts elicited more positive amplitudes than those in other-relevant contexts. This effect was qualified by an interaction between self-relevance and valence from 150-350ms (Table 3c), where the effect was much stronger for positive trials (Figure 8b, bottom three left panels), only ever reaching significance for negative trials (Figure 8b, bottom three right panels) between 250-350ms.

Statistical Effects	150-250ms	250-350ms	350-450ms	450-550ms	550-650ms	650-750ms
3. a) Electrode Cluster	---	F (1.628,89.558) = 10.474, MSE=3.144, p < .001, η_p^2=.160 (LEFT & MID) < RIGHT	F (1.602,88.100) = 17.562, MSE=4.434, p < .001, η_p^2=.242 (LEFT & MID) < RIGHT	F (1.575,86.633) = 17.652, MSE=5.850, p < .001, η_p^2=.243 LEFT < (MID & RIGHT)	F (1.472,80.985) = 8.440, MSE=7.205, p < .002, η_p^2=.133 LEFT < (MID & RIGHT)	F (1458,80.181) = 2.799, MSE=8.370, p < .083, η_p^2=.048 LEFT < (MID & RIGHT)
3. b) Self-relevance	F (1,55) = 5.302, MSE=.820, p = .025, η_p^2=.088 OTHER < SELF	F (1,55) = 30.676, MSE=.982, p < .001, η_p^2=.358 OTHER < SELF	F (1,55) = 16.616, MSE=1.238, p < .001, η_p^2=.232 OTHER < SELF	F (1,55) = 15.912, MSE=1.484, p < .001, η_p^2=.224 OTHER < SELF	F (1,55) = 17.483, MSE=1.785, p < .001, η_p^2=.241 OTHER < SELF	F (1,55) = 30.907, MSE=1.939, p < .001, η_p^2=.225 OTHER < SELF
3. c) Valence by self-relevance	F (1,55) = 5.739, MSE=.558, p = .020, η_p^2=.094 **POSITIVE self-relevance** effect: F (1,55) = 8.395, MSE=.894, p =.005, η_p^2=.132 OTHER < SELF NEGATIVE self-relevance effect: F (1,55) = .091, MSE=.484, p =.764, η_p^2=.002	F (1,55) = 5.352, MSE=1.179, p = .024, η_p^2=.089 **POSITIVE self-relevance effect:** F (1,55) = 28.183, MSE=1.136, p <.001, η_p^2=.339 OTHER < SELF **NEGATIVE self-relevance effect:** F(1,55) = 4.318, MSE=1.026, p =.042, η_p^2=.073 OTHER < SELF	F (1,55) = 2.983, MSE=1.122, p = .090, η_p^2=.051 **POSITIVE self-relevance effect:** F (1,55) = 21.430, MSE=.945, p <.001, η_p^2=.280 OTHER < SELF NEGATIVE self-relevance effect: F (1,55) = 2.587, MSE=1.485, p =.113, η_p^2=.045	---	---	---

Table 3. Statistical effects from the mean amplitude analyses on frontocentral and centroparietal electrodes, organized by time window. The first F value in each box is the result from the omnibus ANOVA. Subsequent lines are for follow up ANOVAs split over the indicated factors, with significant follow-up tests bolded. The direction of significant paired comparisons or main effects are indicated with "<".

Chapter 4: DISCUSSION

While the majority of face perception research has studied how information extracted directly from the face affects face perception, there is recent evidence that the context under which we view faces is important. Situational self-relevance and valence have been shown to have a strong impact on emotional responding to faces, though the time-course of these effects is still unclear (Weiser et al., 2014; Schwarz et al., 2013). Furthermore, it is unclear how these context cues impact the perception of gaze direction, a sign of self-relevance (Conty et al. 2016 & Hamilton 2016) and positive valence (e.g., Strick et al. 2008; Kampe et al. 2001) itself. To address these gaps, the present study manipulated the contextual valence and self-relevance under which direct and averted gaze faces were viewed. We used event related potentials (ERPs) time-locked to face presentation to track the time-course of when context and gaze effects impact face perception. Our results demonstrate that context alters behavioural and neural responding to faces and gaze in a complex manner, and on a different time-course than previously assumed (Weiser et al., 2014).

Self-referential processing is thought to bias information processing towards relevant stimuli (Schmitz & Johnson, 2007), and has been linked to adaptive social functioning (Mitchell, Banaki & Macrae, 2005). In the present study, we replicated the preliminary finding that self-relevance impacts face perception (Weiser et al., 2014; Schwarz et al., 2013), such that self-relevant faces are rated as more arousing than other-relevant faces. Using mean amplitude analyses of ERP waveforms, we tracked this effect at the brain level, and found that the brain distinguishes self- and other-relevant faces earlier than previously reported (Weiser et al., 2014).

While both our group and Weiser et al. (2014) found an increased negativity elicited by self-relevant faces over occipitotemporal electrodes beginning around 250ms (250-750ms in this study; the 220-300ms EPN in Weiser et al., 2014), we found a corresponding increased positivity over frontocentral and centroparietal electrodes just 150-250ms post-face (also note the trending effect of self-relevance on the N170). Our approach of analysing mean amplitudes in 100ms increments instead of selecting a priori time windows to analyze (e.g., the EPN and LPP) is likely why we were able to detect this effect; Wieser et al. (2014) only sampled frontal sites during the LPP time window (between 400-600ms). Importantly, our ERP results demonstrate that the impact of self-relevance is not only fast, but widespread, exerting influence over both frontal and right-lateralized posterior sites. The early time-course of this effect suggests that priming with self-relevance may be putting participants into a specific self-referential processing mode which exerts its effects on all stages of visual perception, not just stages previously implicated in emotional processing (i.e. the EPN and LPP). While the mechanism behind this effect is still unclear, our behavioural results suggest that self-relevance effects on face perception may be arousal-based.

The effect of self-relevance was modulated by situational valence. Self-relevant faces made participants feel more positive than other-relevant faces when the situation was positive, and more negative than other-relevant faces when the situation was negative. Despite previous assumptions that contextual valence and self-relevance are processed independently in the brain (Weiser et al., 2014), we found initial evidence that they are not. Self-relevance impacted the perception of faces within only positive contexts during certain time-windows (150-450ms over fronto-central/centro-parietal sites and 350-550ms over occipitotemporal sites). As Weiser et al. (2014) did not report any analyses over frontal sites before 400-600ms (the LPP), they may have missed this interaction, given that we detected it over frontal sites from 150-450ms. It is also possible that we were able to track this interaction because we included more contextual sentences and trials per condition, and because our sentences were selected to maximize the interaction behaviourally (see section 2.1.2).

It is unclear why the ERP interaction was pronounced only during positive trials, despite both positive and negative trials producing a behavioural self-relevance and valence interaction. One possibility is that the ERP findings may be related to the previously reported self-referential positivity bias, which proposes that individuals interpret positive information as self-relevant and negative information as other-relevant (Heine, Lehman, Markus, & Kitayama, 1999). Several studies have found that this positivity bias is greater for positive descriptors than for negative ones, meaning that people endorse positive descriptors as self-relevant to a greater extent than they deny negative descriptors as being self-relevant (e.g., Aicke et al. 1995; Eiser, Pahl and Prins, 2001; but see Paul & Eiser, 2005 for conflicting evidence). Our ERP findings may reflect this increased sensitivity to self-relevance during positive trials.

Our results demonstrate that context effects do not just exert their influence over face perception during the EPN and LPP time windows, which have been previously linked to emotional processing. However, we did replicate a later valence effect in the typically reported EPN time window (250-350ms post-face over occipitotemporal sites), characterized by an enhanced negativity for faces in negative contexts compared to faces in positive contexts, regardless of self-relevance. While the EPN is typically associated with an enhanced negativity to positive and negative stimuli relative to neutral stimuli (e.g., Herbert et al. 2008; Kissler et al. 2009; Schupp et al. 2006), and we did not include a neutral context condition, many studies have reported a similar increased EPN negativity elicited by negative stimuli than positive stimuli (Rellecke, Palazova, Sommer, & Schacht, 2011; Rellecke, Sommer, & Schacht, 2013; Schupp, Junghöfer, Weike, & Hamm, 2004; Neath & Itier, 2015). However, it should be emphasized that we always measured neural responding to neutral faces, containing no affective information. Thus, emotional modulation in EPN time window can be elicited solely by perceiving neutral faces within different affective contexts. While emotional modulation of this time window has been reported to vary as a function of emotional arousal (Low et al. 2005), our participants reported no arousal difference between positive and negative contexts, suggesting that emotional valence may actually be the key factor at play.

Finally, while the effect of gaze direction on face perception has been studied (e.g., Taylor, Itier, et al. 2001; Watanabe et al. 2002; Puce et al. 2000; Watanabe et al. 2006; Taylor, George, et al. 2001; Senju & Hasegawa 2005), there is a need for systematic investigation into how situational context can affect our response to gaze cues. In the present study, we found that contextual valence and self-relevance alter behavioural and neural responding to gaze in a complex way. Direct gaze is more affectively arousing (Nichols & Champness 1971; Conty et al. 2010), rewarding (Kampe et al. 2001) and preferred (Dubey et al. 2015) than averted gaze and, indeed, our participants reported that direct gaze faces made them feel more aroused and positive. However, these effects were context specific; direct gaze only made participants feel more positive when viewed within positive, self-referential contexts. Similarly, the difference in arousal ratings between direct and averted gaze faces was largest when these faces were put into either positive or self-referential contexts.

Importantly, similar effects were seen at the neural level. Gaze direction affected neural responding only for faces within a positive and self-referential context, driven by more negative ERPs to averted gaze faces. We found this interaction mainly on the N170 ERP component, thought to reflect configural face processing (Eimer, 2000; Sagiv & Bentin 2001). While it must be noted the interaction was relatively weak, it suggests that certain situational contexts may interact with gaze direction to modulate the structural encoding of the face.

The pattern of behavioural and ERP results suggests that positive and self-referential contexts prime sensitivity to averted gaze. Indeed, it is interesting to note that, despite *direct* gaze being both attention grabbing (Senju & Hasegawa 2005) and arousing (Nichols & Champness 1971; Conty et al. 2010), we found *averted* gaze under positive, self-referential contexts to be associated with enhanced visual processing. One possibility is that because direct gaze is a positive (e.g., Strick et al. 2008; Kampe et al. 2001) and self-referential (e.g., Conty et al. 2016; Hamilton 2016; Kampe et al., 2003) cue, it is incongruous and salient to see averted gaze under positive, self-referential contexts. On a social level, it may be somewhat surprising to see someone who has just complemented you avert their gaze. Gaze aversion could mean that a positive conversation partner is starting to lose interest, or alternatively be a signal of coyness or shyness. Indeed, it appears that averted gaze has greater emotional significance than direct gaze in positive, self-referential contexts. As seen in our sentence validation study (when gaze direction is not a factor), positive self-referential contexts elicit more positive emotion than positive other-referential contexts (Fig. 1, positive adjectives). However, when paired with averted gaze faces, as in our EEG experiment, positive self-referential contexts induce no more positive emotion than other-relevant positive contexts with direct or averted gaze; there is actually a *decrease* in positive affect from baseline for these averted gaze faces (Fig. 4a).

We are not the first to report an enhanced N170 to averted gaze (though note that Taylor, Itier, et al. 2001 found no N170 gaze effects). Watanabe et al. (2002) and (Itier et al. 2007b) found that averted gaze faces produced a larger N170 amplitude than direct gaze faces while Puce et al. (2000) found enhanced N170s elicited by dynamic faces shifting from direct to averted gaze rather than from averted to direct (though Watanabe et al. (2006) found the opposite for the M170, the N170 equivalent in magnetoencephalography). Some have also reported shorter N170 latency to averted gaze faces (Puce et al. 2000) and shorter M170 latency for averted eyes (Taylor, George, et al. 2001), suggesting that averted gaze is processed faster. The present study adds to this accumulating evidence that, despite what was previously believed, gaze effects on face processing begin early in the visual processing stream.

It should be noted that this study has a few limitations. First, because we needed to remove noisy trials for the EEG analyses, our EEG analyses were performed on a subset of the behavioural data. This potentially weakens the comparisons drawn between the EEG and behavioural data because they do not contain the exact same trial information. Second, this paradigm relies on self-reporting of emotional states on a trial-by-trial basis. Due to the study length, it is possible that participants became desensitized to the contextual sentences by the end of the study, or were no longer taking the adequate time needed to consider their emotional states before answering.

Finally, while EEG can tell us when effects occur with great temporal precision, it provides weak spatial resolution. However, previous neuroimaging research within this paradigm (Schwarz et al., 2013) found that self-relevance resulted in increased activation in the medial prefrontal cortex (mPFC), and the right inferior-temporal lobe/fusiform gyrus. It seems likely that the negativity for self-relevant faces we found first on frontal sites, and then on right occipitotemporal sites, thus reflects initial mPFC and later right-lateralized fusiform gyrus activation. As this study is the first to incorporate gaze cues into this paradigm, it is difficult to theorize about where in the brain gaze and context cues are integrated. However, the gaze interaction was found only on occipitotemporal sites, potentially because the core brain areas implicated in gaze processing are posterior, including the superior temporal sulcus and inferior parietal cortex (Itier & Batty, 2009; Frischen, Bayliss, & Tipper, 2007). Future functional magnetic resonance imaging research can tease apart where gaze cues within different contexts are processed and whether the mPFC modulates the right fusiform gyrus in a top-down manner, or if they are independently responsive to faces placed within self-referential contexts.

In conclusion, the present study demonstrates that context is important. While, most face processing studies examine facial cues devoid of situational information, our everyday social environment is rich with contextual cues. Here, we have shown that this information can impact our early visual processing and corresponding emotional reaction to the facial cues that we encounter, emphasizing the importance of studying face processing in increasingly ecological scenarios.

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