NeuroImage 226 (2021) 117605

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/neuroimage

Feeling through another's eyes: Perceived gaze direction impacts ERP and behavioural measures of positive and negative affective empathy

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ARTICLE INFO

Keywords:
Gaze direction
Positive and negative empathy
Face perception
ERP
Mass-univariate statistics
Affective sharing

ABSTRACT

Looking at the eyes informs us about the thoughts and emotions of those around us, and impacts our own emotional state. However, it is unknown how perceiving direct and averted gaze impacts our ability to share the gazer's positive and negative emotions, abilities referred to as positive and negative affective empathy. We presented 44 participants with contextual sentences describing positive, negative and neutral events happening to other people (e.g. "Her newborn was saved/killed/fed yesterday afternoon."). These were designed to elicit positive, negative, or little to no empathy, and were followed by direct or averted gaze images of the individuals described. Participants rated their affective empathy for the individual and their own emotional valence on each trial. Event-related potentials time-locked to face-onset and associated with empathy and emotional processing were recorded to investigate whether they were modulated by gaze direction. Relative to averted gaze, direct gaze was associated with increased positive valence in the positive and neutral conditions and with increased positive empathy ratings. A similar pattern was found at the neural level, using robust mass-univariate statistics. The N100, thought to reflect an automatic activation of emotion areas, was modulated by gaze in the affective empathy conditions, with opposite effect directions in positive and negative conditions.. The P200, an ERP component sensitive to positive stimuli, was modulated by gaze direction only in the positive empathy condition. Positive and negative trials were processed similarly at the early N200 processing stage, but later diverged, with only negative trials modulating the EPN, P300 and LPP components. These results suggest that positive and negative affective empathy are associated with distinct time-courses, and that perceived gaze direction uniquely modulates positive empathy, highlighting the importance of studying empathy with face stimuli.

1. Introduction

The eyes are a key component of social interactions (Kleinke, 1986; Emery, 2000; George and Conty, 2008; Itier and Batty, 2009 for reviews). The layman expressions "the eyes are the windows to the soul" and "the eyes always tell the truth", reflect that we look to the eyes of others to help us understand their thoughts and emotions, a cognitive process called theory of mind (Baron-Cohen and Cross, 1992). Furthermore, it has been shown that eye gaze also impacts our own emotional state (e.g. Nichols & Champness, 1971; Conty et al., 2010; McCrackin and Itier, 2018a; Baltazar et al., 2014). It is thus surprising that the impact of eye gaze on empathy (colloquially described as "seeing through another's eyes") has yet to be investigated, given that it is an everyday social process requiring both theory of mind abilities and an emotional reaction.

Although different definitions of empathy exist, in the present paper we define empathy as the sharing of another's emotional state while being aware that the other person is the source of the emotion. That is, the capacity to become affectively aroused by the other's affective valence and intensity (Decety, Lewis & Cowell, 2015; de Vignemont & Singer, 2006; Lieberman, 2007; Kanske et al. 2015), which can occur in response to either positive or negative stimuli (see Morelli, Lieberman & Zaki 2015, for a review). This emotional contagion from the other person results in an emotional response that has the same qualia as that of the other individual (e.g. feeling upset when seeing another person is upset). As argued by Decety, Lewis and Cowell (2015), this emotional or affective empathy can be distinguished from perspective taking or theory of mind (what some refer to as "cognitive empathy"), and from empathic concern for the other individual, though these processes may go hand in hand. In the present study, we investigated the behavioural and electrophysiological impact of perceiving direct and averted eye-gaze on affective empathy judgements in neurotypical individuals. Attention to the eyes has been shown to be reduced in populations with altered affective empathy, including psychopathy (e.g. Dadds et al., 2008; Dadds et al., 2012; Gillespe et al., 2015) but also social anxiety disorder, which preliminary evidence suggests may be associated with im-

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https://doi.org/10.1016/j.neuroimage.2020.117605
Received 11 September 2020; Received in revised form 6 November 2020; Accepted 25 November 2020
Available online 30 November 2020

paired affective empathy for positive emotions (Morrison et al., 2016). The present study investigates whether eye-gaze processing impacts affective empathy in neurotypical individuals, which is an important first step towards determining whether a causal link may exist between eye-gaze processing and affective empathy in other populations.

Perceiving direct gaze results in different cognitive effects than perceiving averted gaze, and these cognitive processes may make it easier for an individual to affectively empathize with others when they display direct gaze. First, direct gaze appears to be more strongly linked to emotion processing, a necessary component of sharing someone's emotions (see Hietanen, 2018 for a review). Indeed, relative to perceiving averted gaze, perceiving direct gaze is associated with increased i) arousal (Nichols and Champness, 1971; Conty et al., 2010; McCrackin and Itier, 2018), ii) positive affect (McCrackin and Itier, 2018), and iii) interoceptive awareness in response to emotional stimuli (Baltazar et al., 2014). Direct gaze perception is also linked to increased activation of brain areas implicated in emotion processing, including the ventral striatum (Strick et al., 2008; Kampe et al., 2001), which may play a key role in reward sensitivity (Cardinal et al., 2002; de la Fuente-Fernández et al. 2002; Schreuders et al. 2018).

Direct gaze is also associated with more accurate discrimination of happy and angry facial expressions (McCrackin & Itier, 2019; Adams & Kleck, 2003; 2005; Sander 2007)[1], and while emotion discrimination is arguably different from understanding or sharing those emotions, it may facilitate later emotional understanding and sharing (Clark et al., 2008). Direct gaze has also been linked to the mimicry of actions (Wang et al., 2010), which is associated with affective empathy (Sonnby-Borgström, Jönsson, and Svensson, 2003) and is argued by some to facilitate the emotional contagion that occurs during affective empathy (e.g. Schuler, Mohnke, and Walter, 2016; Prochazkova & Kret, 2017).

Finally, direct gaze is associated with increased self-referential processing and self-reflection (see Conty et al., 2016 and Hamilton, 2016 for reviews). It signals to an individual that they are the focus of another's attention (Itier and Batty, 2009; George and Conty, 2008), and produces similar brain activation as hearing one's name (Kampe et al., 2003). Gaze processing interacts with the self-relevance of contextual sentences at the electrophysiogical level (McCrackin and Itier, 2018), and individuals report feeling more self-aware (measured by the Situational Self-Awareness Scale; Govern and Marsch, 2001) after seeing direct as opposed to averted gaze, though this has only been reported for live faces (Pönkänen, Peltola, and Hietanen, 2011). Critically, it has been proposed that self-focused attention and reflection allows an individual to draw on their own experiences while making mental state inferences (Mitchell, Banaji & Macrae, 2005; Joireman and Hammersla, 2002; Lombardo et al. 2007) and may also play a role in affectively empathizing with others, helping with simulation of others' affective states within the self (Lieberman, 2007; Joireman and Hammersla, 2002; but see Boyraz and Waits, 2015 for null results).

The present study combined electroencephalography (EEG) with behavioural measures of affective empathy to test the hypothesis that direct gaze might facilitate both positive empathy (i.e. sharing in a positive emotion) and negative empathy (i.e. sharing in a negative emotion). We first validated a set of sentences designed to elicit empathy, ensuring that they elicited the correct affective empathy responses in a separate experiment (see Section 2.2). That is, low empathy with neutral valence for neutral sentences and high empathy with positive or negative valence for positive and negative sentences, respectively (corresponding to positive and negative empathy). These contextual sentences described positive, neutral or negative events happening to other individuals (e.g. "Her newborn was saved/killed/fed yesterday afternoon."). We then presented each sentence during the EEG experiment, followed by a direct or averted gaze image of the person described. Participants were then asked to indicate how much they empathized with that individual, defined as sharing that individual's emotion. Event-Related Potentials (ERPs) were recorded to the face image onset. We predicted that during the negative and positive trials, participants would empathize more with individuals displaying direct than averted gaze while during neutral trials, gaze direction would have less or no impact on participants' responses.

The inclusion of both positive and negative affective empathy conditions was important given the recent research suggesting they are distinct constructs. While both empathy types are positively associated with social competence (Sallquist, 2009) and prosocial behaviour (Telle and Pfister, 2016), some special populations (e.g. Social Anxiety Disorder; Morrison et al., 2016) appear to have specific deficits in only one type of affective empathy. Positive and negative affective empathy also have unique neural substrates (see Morelli, Lieberman and Zaki 2015, for a review). While both are associated with prefrontal cortex activation (Mobbs et al., 2009; Morelli, Sacchet, and Zaki, 2015; Light et al., 2009), positive empathy is associated with neural correlates of positive affect (Sallquist et al., 2009), including the ventral striatum (Mobbs et al., 2009) and negative empathy is associated with neural correlates of negative affect, including the anterior insula and dorsal anterior cingulate cortex (Morelli et al., 2015).

As participants knew that they had to make an empathy judgement on each trial, the ERPs time-locked to the face images allowed us to track the time course of the interaction between the valence of the sentence context, the participant's corresponding affective empathy response, and the visual processing of eye gaze. We analyzed the N170, which occurs around 130-200ms post-face onset (George et al., 1996; Bentin et al., 1996; Eimer, 2000) and is thought to be the earliest reliable face sensitive ERP component (Rossion and Jacques, 2012 for a review) whose sensitivity to gaze is still controversial (as we detail further below). We also analyzed the Early Posterior Negativity (EPN; approximately 200-350ms), a negative deflection recorded over occipitotemporal sites that is enhanced following positive or negative stimuli relative to neutral stimuli, including faces with emotional expressions (Neath and Itier, 2015; Neath-Tavares and Itier, 2016; Itier and Neath-Tavares, 2017; Schupp et al., 2004), verbal material (Herbert et al. 2008; Kissler et al. 2009; Schact & Sommer, 2009) and scenes (Schupp et al., 2004). Finally, we analyzed ERPs most commonly associated with experiencing empathy (see Coll, 2018 for a review). It has to be emphasized that the majority of neuroimaging studies on empathy have focused on empathy judgements made in response to the perception of nociceptive stimulation in others (e.g. hands being cut by scissors or trapped under a cabinet door) in comparison to neutral stimulations (e.g. hands just next to the scissors or atop the cabinet door). ERP components recorded in those paradigms included the N100 (approximately 50–120 ms) and N200 (200–350 ms) over frontal sites (though occasionally this time-window is measured as a P200 over posterior sites), and the P300 (300–500 ms) and Late Positive Potential (LPP, 500–800 ms, though see Decety et al., 2015 for 400–1000 ms) over centroparietal sites. These ERP components, described in more details below, typically differentiate pain-inducing stimuli relative to neutral stimuli, though the direction of the N100 and N200 effects has been mixed Coll (2018). The interpretations of these early and late ERP modulations are informed by theories of affective empathy which involves early automatic processes during which an emotional state is elicited in an observer, and then is modulated by later top down processes (e.g. Preston and de Wall, 2002; Decety and Lamm, 2006).

It has been argued that the early N100 and N200 are insensitive to task demands, and that they may reflect an initial automatic activation of emotion areas elicited by the perception of painful stimuli (Fan and Han, 2008), perhaps through the activation of the mirror neuron system (Gallese & Goldman, 1998) that contribute to a later "emotional

[1] It should be noted that there is also some support for the idea that sad and fearful expressions are easier to perceive with *averted* gaze (Adams & Kleck, 2003; Sander et al., 2007), though the results of those initial studies may have been tied to the specific stimulus set used (Graham & LaBar, 2007; Bindemann et al., 2008).

sharing” response. By “emotional sharing”, researchers usually mean that participants need to somehow experience the pain for themselves in order to judge the intensity of the pain experienced by the people whose body parts were shown. However, recent findings from Decety et al. (2015) suggest that task demands can modulate ERPs during the N200 time-window. Not only were there greater amplitudes for pain images than neutral images from 175–275 ms during an affective sharing task (indicating the pain intensity), but the same stimuli elicited larger amplitudes at this time during the affective sharing task than during an emotional compassion task (indicating how sorry they felt for the individual). If these components do reflect emotion area activation during affective sharing, in the present study these components should be enhanced during positive and negative trials relative to neutral trials. If these components are further modulated by eye-gaze, it would suggest that eye-gaze can modulate the early activation of emotion areas.

In contrast, the later P300 and LPP components are more commonly found to be task sensitive, and may reflect a cognitive evaluation of the situation which is subject to top-down regulation (Fan and Han, 2008; Decety, Yang and Cheng, 2010; see Decety and Lamm, 2006 and Gonzalez-Liencres et al., 2013, for more discussion). Similar to the early components, Decety et al. (2015) found that the LPP amplitude was greater for pain images than neutral images, and was greater during the affective sharing task than during the emotional compassion task. If these later components do indeed reflect cognitive evaluation of affective sharing, they should also show enhancement during our positive and negative trials relative to neutral trials. If eye-gaze further modulates this enhancement, it would suggest that eye-gaze impacts the cognitive evaluation of the affective empathy response to the faces.

While previous empathy ERP findings primarily stem from paradigms that display body parts interacting with painful stimuli (i.e. hands, feet, and/or faces getting pricked with needles; e.g. Decety, Yang and Cheng, 2010; Cheng, Chen and Decety, 2014) or faces with pained expressions (e.g. Sheng and Han, 2012), there is reason to believe that these ERP components reflect processes that occur during affective empathy that are not specific to physical pain. For example, some have claimed that they relate to trait empathy as measured by self-report questionnaires, a construct which is arguably broader than pain empathy. One study had participants complete an oddball task (responding to a mosaic pattern) while viewing positive and negative stimuli depicting either human facial expressions of emotions or scenes, with the assumption that the human emotion stimuli would elicit more empathy than scenes (Groen et al., 2013). In this study, the N100 (measured posteriorly in this case) was more negative, and the anterior N200 was more positive, in response to positive human emotions than positive scenes. The magnitude of this human-scene amplitude difference was positively correlated with self-reported trait empathy (Groen et al., 2013), though it is likely that these early ERP effects were driven by differences in low-level features between the image categories. In another study, N200 amplitudes were also larger in response to emotional faces compared to neutral faces during a no-emotion/emotion discrimination task, with more positive amplitudes to emotional faces for those with higher trait empathy (Balconi and Canavesio, 2016). Regarding the later ERP components, Decety et al., (2015) found that trait empathy was positively correlated, and psychopathy traits were negatively correlated, with LPP difference waves for painful compared to neutral stimuli. However this was only the case during their empathic concern task, and not during their affective sharing task. Higher self-reported empathy has also been associated with more positive LPP amplitudes to target facial expressions amongst other expressions during an oddball task (Choi and Watanuki, 2014). Finally, LPP amplitudes were found to be more positive in response to negative human stimuli relative to negative scenes, and the magnitude of this difference was correlated with self-reported empathy (Groen et al., 2013). These findings would suggest that these ERP components reflect processes that may also be active during our affective empathy task, which is important to confirm to further develop our understanding of what processes these components reflect.

In the gaze processing ERP literature, recent findings suggest that eye-gaze from a face picture might be processed as early as 100-140ms after face onset, with one group reporting more positive amplitudes for direct than averted gaze (e.g. Burra et al., 2018) and another reporting the opposite (Schmitz et al., 2012). These findings would suggest that eye-gaze is processed around the same time as the N100 ERP component sensitive to empathy. Others have reported that gaze direction is discriminated during the N170. Some have reported that the N170 is more negative in response to dynamic averted gaze shifts (Latinus et al., 2015; Puce et al., 2000; Rossi et al., 2015) or averted gaze face images (Itier et al., 2007; Watanabe et al., 2002) than to direct gaze counterparts. Others have found the opposite pattern of results, with more negative N170 amplitude following direct gaze static images (Burra et al., 2017; see also Pönkänen et al., 2010 with live faces) and dynamic direct gaze shifts (Conty et al., 2007; Watanabe et al. 2006). In contrast, some studies have found no detectable difference between direct or averted gaze processing on the N170 (see Pönkänen et al., 2010 with face pictures; Taylor et al., 2001; Schweinberger et al., 2007; Rossi et al., 2015 with line drawn faces; McCrackin & Itier, 2019 with pictures of facial expressions). Later time windows, ranging from 250–350 ms (Schweinberger et al., 2007) or 300–600 ms (Conty et al., 2007; Burra et al., 2018; Itier et al., 2007) have typically reported more positive amplitudes for direct than averted gaze.

While taken together, these findings appear quite mixed on the surface, the eye-gaze literature is increasingly demonstrating that direct and averted gaze processing varies as a function of the task being performed (McCrackin and Itier, 2019; Burra et al., 2018; Latinus et al., 2015; Carrick et al., 2007; Hooker et al., 2003; Hoffman and Haxby, 2000). The different tasks used in each study may explain some of the variation in findings. For example, the earlier N170 gaze effect has been proposed to be due to changes in luminance and contrast that occur during the perception of dynamic gaze stimuli (e.g. Conty et al. 2007; see Puce et al. 2015 for a review). However, even if it is driven by lower level aspects of stimulus features, this eye-gaze effect on the N170 still appears to be linked to the social significance of the task participants are performing (Latinus et al., 2015). The importance of task demands was also highlighted recently through different eye-gaze effects over frontal sites from 220-290ms seen across three different tasks performed by the same participants (McCrackin and Itier, 2019).

Another factor which may contribute to mixed ERP findings associated with both eye-gaze (see Itier and Batty, 2009) and empathy (see Coll, 2018) concerns the type of ERP analyses performed in each study. Traditional ERP practices like examining waveforms before selecting which electrodes and time-points to include in an analysis have likely contributed to the mixed results by inflating type I error (Luck and Gaspelin, 2017; Coll, 2018). As Luck and Gaspelin (2017) describe, this method involves many “implicit visual comparisons” performed by the researchers that go uncorrected for. At the other extreme, type II error can occur when only *a priori* electrodes and time-windows are analyzed, preventing the discovery of unpredicted but real effects. While ERP analysis techniques trade-off between these two types of errors, the recently developed mass univariate ERP analysis technique shows great promise (Fields & Kuperberg, 2018; Groppe et al., 2011; Luck & Gaspelin, 2017; Pernet, et al., 2011; Pernet et al., 2015). Hypothesis testing can be performed for each time-point and electrode of interest with an applied multiple comparison correction to reduce type I error. An exploratory analysis can also be run on all electrodes and time-points to allow for the discovery of unpredicted effects. This can reduce type II error, with the caveat that this analysis will have low power following multiple comparison correction (due to the large number of comparisons made). In the present study, we analyzed our ERP data with the free Factorial Mass Univariate Toolbox (FMUT) extension (Fields, 2017) for the Mass Univariate Toolbox (MUT; Groppe et al., 2011), performing exploratory as well as hypothesis driven analyses.

In summary, we hypothesized that the perception of direct gaze of an individual subjected to positive or negative situations would increase participants' affective empathy for that person, and that this effect would impact early and/or late ERPs associated with affective empathy processes. Mixed results in the ERP eye-gaze processing literature, however, made it hard to offer specific predictions as to the direction of these modulations. The components of interest included ERPs believed to reflect the early activation of brain areas sensitive to emotional stimuli (N100 and N200) and the attentional selection (EPN) and cognitive appraisal (P300 and LPP) of emotional stimuli. Furthermore, we predicted that all of these ERPs would be enhanced for positive and negative trials relative to neutral ones, reflecting those various stages of emotional processing. We start by reporting the empathy sentence validation study before moving on to the ERP study on empathy and gaze processing.

2. Methods

2.1. Online sentence validation study

2.1.1. Participants

This study was approved by the University of Waterloo (UW) Research Ethics Board, and 76 UW students with normal or corrected-to-normal vision participated for course credit. Seven participants were excluded for leaving more than ten percent (48) of the 480 questions blank, leaving a final sample of 69 participants (36 female, $M = 19.88$ years, $SE = .24$). Thirty-three participants (16 female) were randomly assigned to the male pronoun group and 36 (20 female) to the female pronoun group as described below. Participant ethnicity in the final sample varied (Caucasian: $n = 23$; Chinese: $n = 17$, Other Asian Groups: $n = 15$; East Indian: $n = 4$; Aboriginal: $n = 2$, Middle Eastern: $n = 2$, Other: $n = 6$).

2.1.2. Sentence construction

Sentences that varied in the amount of empathy they elicit were created for later use in the EEG-Eye tracking study. Eighty overall *sentence themes* were created, with a positive, negative and neutral variation of each, created by altering key words in the sentence (e.g. "his pet dog was saved/killed/fed yesterday"). The neutral sentences were designed to carry content as neutral as possible, so that participants would not feel much empathy for the individuals described in them. These would act as baseline low-empathy sentences. The positive and negative sentences were designed to elicit more empathy, varying in valence. All sentences contained eleven syllables and wherever possible, sentence structure for each of these valence variations was kept identical. Some sentences were adapted from those used by Hudson (2018). This resulted in 80 sentences for each valence category, for a total of 240 sentences.

2.1.3. Study design and data analysis

To keep the study length under an hour and a half, one study version was created with male pronouns used at the beginning of the sentences, and another version was created with female pronouns (e.g. "he/she was hugged by his/her mom after the meal"). Participants were randomly assigned to one of the two study versions, with random sentence presentation order.

Participants rated each sentence on how much empathy they felt for the individual described in the sentence using a 9-point Likert scale. A rating of 1 meant very little empathy and a rating of 9 meant extreme empathy. Empathy was defined as "sharing of another's emotional state, while being aware that the other person is the source of the emotion" (De Vignemont and Singer, 2006). Participants also rated the valence of the emotion elicited by the sentence, where a rating of 1 meant very negative and a rating of 9 meant very positive. Participants rated 238.55 ($SE = .25$) sentences on average.

Ratings of the male and female pronoun versions of each sentence were combined for data analysis. For each of the 80 sentence themes, there were positive, negative and neutral variations, and ratings of empathy were averaged across participants for each of these variations (Table 1). Ratings of the valence of the emotion elicited by each sentence were averaged in the same manner.

The key purpose of this validation was to find the sentence themes in which the positive and negative variations elicited significantly more empathy than the neutral variations. Toward this end, an "overall empathy score" was calculated to quantify how much more empathy was elicited by the positive and negative variations relative to the neutral baseline[2]. Here, any score above 0 meant that the positive and negative variations elicited more self-reported empathy than the neutral variation, with the higher the score, the better. Overall, the created sentences were successful: all empathy scores were above 0, with an average score of 3.60. However, we wanted to ensure that we were choosing only the above average sentence themes, so we chose the sentence themes that had an empathy score of 4 or greater. This meant that participants rated the positive and negative variations as eliciting (on average) at least 2 more points on the empathy Likert scale than the neutral variation. This cut-off point corresponded to 29 sentence themes, and for counterbalancing purposes, we rounded to an even number of the top 25 (i.e. excluding approximately the bottom 70% of sentences). All twenty-five selected themes were used in the later EEG-eye tracking study (starred in Table 1), and statistically analyzed below to confirm that 1) the positive and negative sentence variations elicited significantly more empathy than the neutral variation and 2) neutral sentences elicited an intermediate (neutral) emotion, while positive sentences elicited more positive emotion than both negative and neutral sentences, and negative sentences elicited more negative emotion than both neutral and positive sentences.

A positive empathy, negative empathy and neutral empathy average for each participant was created by averaging empathy ratings for the three variations of the selected 25 sentences. A positive valence, negative valence, and neutral valence average for each participant was also created by averaging valence ratings for the variations of the final sentences. Two Analyses of Variance (ANOVA) with a factor of sentence valence (3; positive, neutral, negative) were run, one on the empathy averages and the other on the valence averages. The raw *p*-values for the follow up comparisons are reported, such that $p<.016$ would reach threshold for significance with Bonferroni correction ($p<.05/3$ for the three comparisons run). Cohen's *d* and it's 95% confidence interval was calculated using the free software Psychometrica.

2.1.4. Results for the selected 25 sentence themes

Empathy ratings – There was a main effect of sentence valence on ratings of affective empathy (Fig. 1a), $F(1.50, 102.47) = 152.03$, $MSE = 1.08$, $p < .001$, $\eta_p^2 = .69$. Follow-up paired t-tests indicated that there were significantly higher empathy ratings during the negative condition than both the neutral, $t(68) = 13.42$, $MSE = .22$, $p < .001$, Cohen's d= -1.64 (95% CI for d [-2.027, -1.261]), and positive conditions, $t(68)$= 4.01, MSE= .12, $p < .001$, $d = -0.481$ (95% CI for d [-0.817, -0.145]). There were also significantly higher empathy ratings during the positive condition than during the neutral condition, $t(68)$= 13.22, $MSE = .18$, $p < .001$, $d = 1.56$ (95% CI for d [1.182, 1.939]).

Valence ratings – There was a main effect of sentence valence (Fig. 1b), $F(1.11,75.32) = 444.99$, $MSE = 1.76$, $p < .001$, η_p^2=.87. Paired t-tests confirmed that the positive condition elicited more positive emotion than both neutral, $t(68)$= 18.24, MSE= .11, $p < .001$, d=-1.85 (95% CI for d [-2.249, -1.451]), and negative conditions, $t(68)$= 21.60, MSE= .23, $p < .001$, d=-2.58 (95% CI for d [-3.027, -2.124]). The negative

[2] Taken by summing the difference between the positive and neutral empathy ratings, and the difference between the negative and neutral empathy ratings ((positive empathy – neutral empathy) + (negative empathy – neutral empathy)). The larger this score, the more empathy participants felt elicited by the positive and negative variations of the sentence theme relative to the neutral variation.

Table 1
Validation results for each of the original 80 sentence themes, with mean empathy and valence ratings (*SE* in parentheses) averaged across all 69 participants as a function of sentence valence (positive, neutral and negative). The 25 starred sentences were selected for the EEG-Eye tracking experiment. Note: All sentences began with he/she or his/her.

Sentence Theme	Positive Empathy	Positive Valence	Negative Empathy	Negative Valence	Neutral Empathy	Neutral Valence	Overall Empathy Score
***pet dog was saved/fed/killed yesterday afternoon	6.80(.25)	7.42(.22)	7.26(.24)	1.94(.17)	3.90(.26)	5.31(.17)	6.26
***pet cat was found/fed/lost yesterday afternoon	5.99(.25)	6.94(.21)	6.44(.22)	3.13(.20)	3.59(.23)	5.28(.15)	5.25
was just told that he(she) will soon/should go/will not walk again	6.84(.24)	7.91(.18)	7.33(.26)	1.82(.19)	4.93(.25)	5.59(.20)	4.31
***loves/does/hates the job and the boss that he(she) works with	5.62(.26)	7.16(.17)	6.28(.25)	2.87(.19)	3.57(.24)	5.06(.11)	4.76
work environment is very friendly/standard/hostile	5.50(.24)	6.90(.18)	6.01(.24)	2.83(.17)	3.79(.23)	4.87(.07)	3.93
***learned he(she) does not have/has learned now all about/learned he(she) does now have/ the deadly disease	6.93(.25)	7.75(.21)	7.30(.25)	2.75(.32)	4.78(.30)	4.59(.20)	4.67
really loves/knows/hates the way that his(her) body looks	5.59(.26)	7.32(.18)	6.49(.24)	2.54(.17)	4.83(.21)	5.65(.16)	2.42
often thinks that all his(her) children love/know/hate him(her)	5.51(.23)	6.97(.21)	6.30(.26)	2.26(.16)	4.41(.25)	5.31(.18)	2.99
always believes that he(she)/often believes the show/never believes that he(she) could start over	5.37(.26)	5.90(.19)	5.72(.25)	3.32(.18)	4.10(.26)	5.01(.13)	2.89
***partner's life was saved/partner went shopping/partner's life was lost yesterday morning	7.41(.22)	7.87(.20)	7.88(.21)	1.78(.21)	3.49(.24)	5.16(.11)	8.31
mom's life was saved/ book ended/life was lost after a heart attack	7.36(.21)	7.90(.21)	7.63(.24)	1.54(.15)	5.90(.29)	3.10(.23)	3.19
***son's life was saved/son was delayed behind/son's life was lost after a bad car crash	7.30(.22)	7.65(.24)	7.94(.22)	1.57(.17)	5.30(.26)	3.81(.20)	4.64
***was just reunited with/doing housework with/separated from his(her) partner	6.28(.24)	7.26(.18)	6.49(.23)	2.49(.15)	3.94(.26)	5.59(.12)	4.89
***child was reunited with/at his workplace with/separated from him(her) today	6.94(.25)	7.77(.17)	7.16(.25)	1.97(.19)	4.48(.26)	5.98(.14)	5.14
***dog was reunited with/eating her food/taken away from him(her) today	6.72(.24)	7.36(.20)	7.01(.25)	2.38(.19)	4.68(.27)	6.09(.17)	4.37
was rewarded/walking by/disciplined in front of the whole team	5.74(.26)	7.04(.20)	5.98(.26)	3.15(.21)	4.00(.23)	4.84(.10)	3.72
was rewarded/walking by/disciplined in front of the whole school	5.76(.26)	7.18(.19)	6.10(.26)	2.68(.20)	4.00(.27)	4.96(.13)	3.86
was hugged/called/punched by his(her) teammate after the game	4.97(.25)	6.58(.16)	6.00(.21)	2.91(.18)	3.99(.22)	5.43(.11)	2.99
was hugged/called/punched by the coach after the big game	5.17(.25)	6.42(.18)	6.10(.26)	2.51(.19)	4.38(.25)	5.21(.14)	2.51
was hugged/called/slapped by his(her) mom after the meal	5.10(.28)	6.67(.17)	6.55(.24)	2.36(.15)	4.36(.29)	5.81(.16)	2.93
mom embraced/spoke with/punished him(her) after the fundraiser	5.64(.27)	6.41(.25)	5.90(.25)	3.01(.19)	4.04(.23)	5.14(.09)	3.46
won/saw/lost the hardest music competition	5.90(.27)	7.36(.18)	6.00(.24)	3.04(.17)	3.82(.26)	5.18(.13)	4.26
just won/saw/lost the basketball game for his(her) team	5.74(.26)	7.35(.16)	5.68(.24)	3.07(.18)	3.80(.25)	5.32(.12)	3.82
just won/saw/lost the world cup final for his(her) team	5.87(.29)	7.77(.17)	6.22(.28)	2.69(.20)	4.26(.26)	5.86(.17)	3.57
just won/saw/lost the ice skating competition	5.62(.26)	7.22(.17)	5.62(.24)	3.09(.14)	3.71(.23)	5.45(.23)	3.82
***aced his(her)/marked the/failed his(her) very important driving test	5.77(.27)	7.19(.15)	6.28(.23)	3.01(.18)	3.84(.25)	5.22(.13)	4.37

(*continued on next page*)

Table 1 (*continued*)

Sentence Theme	Positive Empathy	Positive Valence	Negative Empathy	Negative Valence	Neutral Empathy	Neutral Valence	Overall Empathy Score
***aced his(her)/marked the/failed his(her) very important physics test	6.26(.27)	7.22(.23)	6.49(.23)	2.77(.17)	3.74(.25)	5.29(.13)	5.27
***aced his(her)/marked the/failed his(her) very difficult psych exam	5.97(.27)	7.49(.18)	6.47(.27)	2.63(.16)	4.03(.27)	4.75(.14)	4.38
***aced his(her)/marked the/failed his(her) very difficult math exam	6.09(.28)	7.49(.18)	6.86(.22)	2.52(.16)	3.73(.25)	5.04(.13)	5.49
just bought/saw/broke an amazing new vehicle	4.94(.28)	6.85(.17)	5.81(.25)	2.99(.17)	4.13(.30)	5.86(.15)	2.49
just won/saw/crashed a fast and expensive new car	4.84(.29)	7.07(.20)	5.86(.26)	2.49(.16)	3.57(.27)	5.22(.17)	3.56
just won/saw/broke a powerful new computer	4.88(.28)	6.86(.16)	5.62(.27)	2.90(.15)	3.81(.27)	5.56(.14)	2.88
just won/saw/missed the award he(she) was working hard for	6.43(.25)	7.57(.15)	6.59(.22)	3.00(.17)	4.81(.17)	5.77(.17)	3.40
fixed his/saw his/broke his old Nintendo and controller	5.25(.23)	6.41(.19)	5.16(.26)	3.67(.18)	4.84(.29)	6.15(.18)	0.73
amazing new/official work/terrible new computer just arrived	4.88(.29)	6.67(.18)	4.01(.24)	3.88(.15)	3.85(.28)	5.75(.15)	1.19
loves/knows/hates the new school he(she) has to enroll in	5.52(.26)	7.16(.17)	6.04(.25)	2.99(.17)	4.29(.25)	5.32(.14)	2.98
loves/knows/hates the cell phone he(she) got for his birthday	5.20(.28)	6.64(.19)	3.42(.27)	3.48(.18)	4.00(.27)	5.44(.12)	0.62
***knows his partner is so in love/not shopping/not in love with him(her)	5.99(.27)	7.68(.17)	7.07(.19)	2.22(.18)	3.93(.24)	5.19(.27)	5.20
was adored/noticed/hated by all of his(her) new classmates	5.19(.27)	7.01(.19)	6.55(.27)	2.15(.17)	4.47(.24)	5.78(.15)	2.80
was accepted to be on/quite interested in/rejected to be on the best team	5.57(.27)	7.15(.20)	6.04(.24)	3.19(.16)	4.00(.25)	5.36(.12)	3.61
***was accepted/also there/rejected at the job interview	6.43(.23)	7.43(.17)	6.53(.24)	2.88(.17)	3.75(.23)	5.04(.09)	5.46
***got accepted by/to read about/rejected by the school he(she) wanted	6.76(.24)	7.56(.16)	6.67(.22)	2.84(.18)	4.07(.24)	5.83(.15)	5.29
just got hired by/read all about/got fired from his(her) all-time dream job	6.03(.29)	7.76(.17)	6.65(.26)	2.12(.17)	4.65(.30)	6.13(.20)	3.38
***partner told him(her) she(he) really does love him(her)/really does love cats/no longer loves him(her)	6.76(.23)	7.44(.24)	7.23(.22)	2.00(.14)	3.96(.27)	5.64(.27)	6.07
***knows right now that his(her) partner is faithful/shopping/cheating	6.03(.26)	7.32(.19)	6.57(.29)	2.26(.22)	3.73(.23)	5.16(.10)	5.14
***insurance will pay for all/needs a code for/will not pay for the treatment	6.41(.25)	7.52(.21)	7.09(.21)	2.44(.18)	4.55(.24)	4.38(.14)	4.40
newborn baby is doing very well/currently asleep/doing very bad	5.96(.28)	7.71(.17)	7.07(.26)	1.91(.15)	4.84(.24)	6.09(.15)	3.35
mom cherishes/remembers/despises the day that he(she) was born	6.26(.26)	7.53(.18)	6.87(.30)	1.74(.18)	5.43(.28)	6.97(.18)	2.27
***partner has decided to marry/drive with/divorce him(her)	6.19(.29)	7.94(.16)	6.74(.24)	2.41(.19)	4.16(.26)	5.75(.13)	4.61
overheard his partner say she's(he's) happy/hungry/lonely	5.83(.26)	7.32(.17)	6.33(.23)	2.78(.16)	4.18(.26)	4.80(.14)	3.80
is excited/beginning/terrified to move out on his(her) own	5.76(.24)	7.07(.18)	6.01(.27)	3.46(.18)	5.77(.26)	6.38(.19)	0.23
life savings quadrupled/we counted/disappeared during the week	5.57(.28)	7.41(.20)	6.37(.26)	2.34(.26)	4.19(.23)	5.21(.13)	3.56
earned the/counted/lost the money for his(her) dream apartment	5.83(.25)	7.26(.17)	6.58(.26)	2.65(.26)	4.65(.25)	5.96(.17)	3.11
fundraised/counted/misplaced money for the homeless shelter	5.83(.26)	7.29(.16)	5.30(.25)	2.94(.17)	4.91(.24)	6.16(.18)	1.31
boss thinks that he(she) is quite intelligent/still undecided/unintelligent	5.52(.27)	6.88(.19)	5.91(.26)	2.81(.16)	4.39(.24)	4.32(.11)	2.65
told his mom that his(her) father is loving/eating/cheating	5.01(.29)	6.85(.19)	6.62(.28)	2.09(.18)	3.84(.27)	5.12(.13)	3.95

(*continued on next page*)

Table 1 (*continued*)

Sentence Theme	Positive Empathy	Positive Valence	Negative Empathy	Negative Valence	Neutral Empathy	Neutral Valence	Overall Empathy Score
just attended his (her) mother's fun party/appointment/funeral	4.48(.24)	6.49(.15)	7.62(.23)	1.84(.19)	4.32(.26)	4.96(.10)	3.46
will definitely get his/lose his/see the dream house soon	5.75(.26)	7.10(.19)	5.59(.27)	3.14(.20)	4.74(.25)	6.38(.18)	1.86
has laughed/read/cried more times today than he(she) can count	5.71(.28)	7.42(.18)	6.67(.22)	2.59(.18)	4.06(.25)	5.28(.18)	4.26
looks back on his past with a lot of joy/quite objectively/with a lot of guilt	5.78(.27)	7.23(.17)	6.14(.26)	2.87(.19)	5.04(.27)	4.83(.16)	1.84
happily relaxed/ate a small dinner/cried hard to himself(herself) after his(her) big game	5.19(.29)	6.44(.19)	6.09(.24)	3.29(.21)	4.09(.26)	5.07(.15)	3.10
class environment is very friendly/standard/hostile	5.25(.24)	7.03(.17)	6.07(.23)	2.93(.18)	4.01(.25)	5.16(.09)	3.30
***cat's life was saved/toy was bought/life was lost yesterday afternoon	6.07(.26)	7.29(.21)	7.00(.25)	2.26(.20)	3.57(.25)	5.45(.13)	5.93
***pet dog was found/fed/lost yesterday afternoon	6.46(.24)	7.55(.19)	6.77(.22)	2.41(.17)	3.94(.24)	5.42(.15)	5.35
loves his(her) class and/goes to class with/hates his(her) class and the students he(she) works with	5.54(.25)	7.04(.17)	5.68(.27)	2.61(.16)	4.10(.25)	5.48(.10)	3.02
daughter's cancer is starting to leave her/class is staring today/is starting to kill her	6.99(.23)	7.75(.19)	7.74(.24)	1.64(.17)	5.99(.26)	3.78(.22)	2.75
believes his(her) marriage is a big success/marriages are a big promise/his(her) marriage is a big failure	5.59(.25)	7.48(.18)	6.04(.28)	2.41(.18)	4.99(.30)	5.74(.21)	1.65
best friend is moving very close to /with some help from/very far from him(her)	5.90(.25)	7.16(.19)	6.81(.24)	2.75(.17)	4.55(.25)	5.59(.18)	3.61
has been feeling more happy/busy/depressed recently	5.94(.22)	7.10(.19)	6.94(.18)	2.72(.20)	5.29(.29)	4.75(.16)	2.30
parents are always/sometimes/never supportive of him(her)	6.39(.26)	7.46(.21)	6.71(.27)	2.49(.23)	5.31(.25)	4.69(.18)	2.48
feels like a superstar/a normal guy(girl)/an imposter living his(her) life	5.16(.26)	6.93(.19)	6.29(.23)	2.80(.19)	4.52(.29)	5.84(.17)	2.41
***close childhood friend just passed by/passed the store/passed away today	6.58(.28)	3.41(.30)	7.55(.23)	1.74(.16)	4.32(.27)	5.68(.19)	5.49
***found an organ match to save/studied organ matches with/ found no organ match to save his(her) sister	6.99(.27)	8.01(.17)	7.41(.24)	2.09(.24)	4.84(.26)	5.20(.19)	4.72
feels he(she) is the cause of their happiness/decision/great sadness	5.58(.25)	6.83(.20)	6.52(.20)	2.52(.18)	5.31(.26)	4.48(.16)	1.48
just found out that the cancer has left him(her)/cancer class began/cancer has left him(her)	7.25(.23)	8.33(.13)	7.56(.23)	1.76(.16)	5.42(.27)	3.78(.18)	3.97
will enjoy seeing/begin to see/now never see his(her) child grow up	5.83(.26)	7.43(.18)	7.39(.25)	1.94(.19)	5.88(.25)	7.22(.18)	1.46
just found out that he(she) is not paralysed/all about paralysis/that he(she) is now paralysed	6.87(.25)	7.97(.19)	7.43(.25)	1.75(.15)	6.30(.30)	2.90(.23)	1.70
has never been in such great shape/really watched/in such bad shape before	5.59(.29)	6.87(.22)	5.91(.24)	3.10(.17)	4.25(.25)	4.75(.16)	3.00
grandfather always remembers his(her) name/does not remember that name/does not remember his(her) name	5.66(.29)	7.00(.19)	6.97(.24)	2.51(.18)	5.70(.29)	3.33(.19)	1.23
***newborn was saved/fed/killed yesterday afternoon	7.28(.23)	7.93(.21)	7.78(.24)	1.41(.13)	3.99(.25)	5.60(.16)	7.08

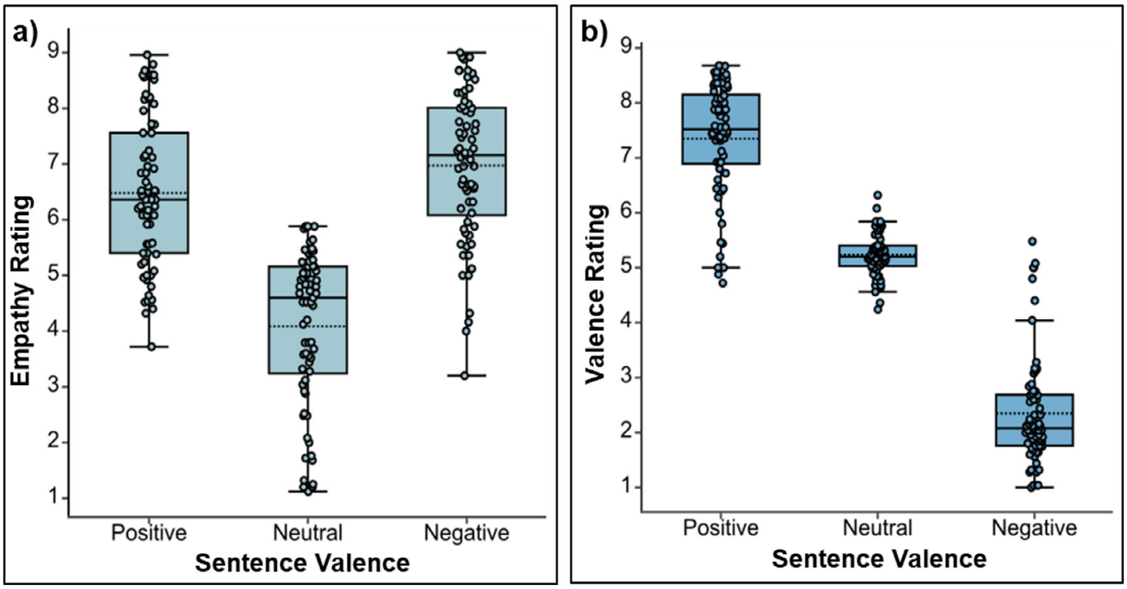

Fig. 1. a) Participants' mean affective *empathy* ratings for the 25 chosen sentence themes in the sentence validation study. **b)** Participants' mean *valence* ratings for the selected sentence themes in the sentence validation study. Each point represents the average from one participant. Boxes indicate participant averages falling between the 25th and 75th percentiles, with the dotted horizontal line representing the mean and the solid horizontal line representing the median.

condition elicited significantly more negative emotion than the neutral condition, $t(68)= -21.42$, $MSE= .13$, $p < .001$, $d=5.00$ (95% CI for d [-5.686 - -4.329]).

2.2. EEG-eye-tracking study

2.2.1. Participants

Fifty (50) undergraduate students at the University of Waterloo (UW) participated in this study and received either course credit or $20 CAD as remuneration. The study was approved by the UW Research Ethics Board, and informed consent was obtained before each individual participated. Five participants were excluded from analysis for failing to complete enough trials, and one for responding with the same answer on each trial, leaving a final sample of 44 (23 female, 21 male; mean age = 20.18 (*SD*=1.56))[3]. All participants were prescreened such that they had corrected-to-normal or normal vision, no neurological or psychological disorders, no current recreational drug use, and had never experienced a loss of consciousness longer than 5 minutes. They also self-reported their ability to recognize both faces and facial expressions as at least a 7/10 on a Likert scale to ensure intact face perception, and had lived in either Canada or the United States for at least 5 years. Participant ethnicity varied (Caucasian: $n = 16$, Chinese: $n = 17$, Other Asian Groups: $n = 5$, Hispanic: $n = 1$, East Indian: $n = 2$, Korean: $n = 1$, Middle Eastern: $n = 1$, and Other Not Listed: $n = 1$).

2.2.2. Face stimuli

Direct gaze, averted left gaze and averted right gaze images of 10 males and 10 females were selected from the Radboud database (Langer et al., 2010)[4]. Each image was flipped along the vertical axis to create a second set of images, which controlled for any facial asymmetry (Fig. 2; e.g. a flipped averted right gaze image became a second averted left gaze image). All individuals were Caucasian and bore a neutral expression. The photos were cropped with the GNU Image Manipulation Program (GIMP 2.8) to display the upper shoulders and head. The SHINE package (Willenbockel et al., 2010) was used to equate images on root mean square contrast ($M = 0.63$, $SD = 0.0004$), and mean pixel intensity ($M = 0.44$, $SD = 0.0004$), and then custom matlab scripts added the colour information back in for increased ecological validity.

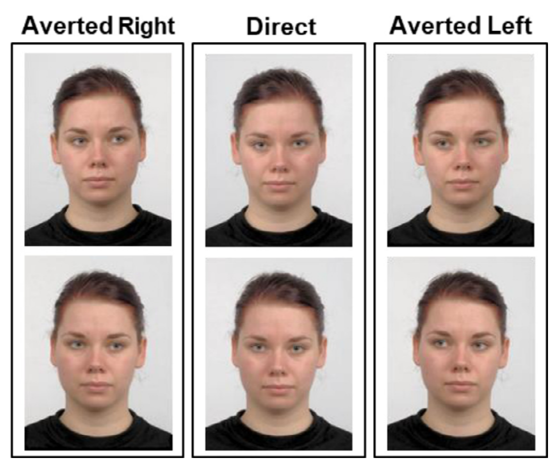

Fig. 2. Sample averted right, direct and averted left gaze stimuli.

2.2.3. Experimental design

After providing informed consent, participants completed a demographics form and were fitted with an EEG cap. The computer task was completed in a sound-attenuated faraday cage with dim lighting. Participants' were situated in a chin rest 65 cm from the CRT monitor displaying the task (refresh rate: 85 Hz, resolution: 1280 × 960), while their dominant eye (determined with the Miles test; Miles 1930) was tracked using an Eyelink 1000 Eye-tracker.

A sample trial progression can be seen in Fig. 3. Each trial began with a positive, negative or neutral sentence, designed to elicit positive, nega-

[3] As there are no previous investigations on eye-gaze and empathy, there were no effect sizes upon which to base our sample size *a priori*. However, sample size for this study was chosen to match or exceed previous samples in other ERP papers on empathy (typically 15-30 as summarized in Coll, 2018). A post hoc analysis with G*power suggests that the smallest effect size we could detect with 80% power was d=.38.

[4] Identities 1, 10, 12, 15, 19, 23, 24, 25, 27, 30, 31, 32, 33, 36, 37, 38, 49, 56, 58, 61 were used in the study blocks, and identities 07 and 14 were used in the practice trials.

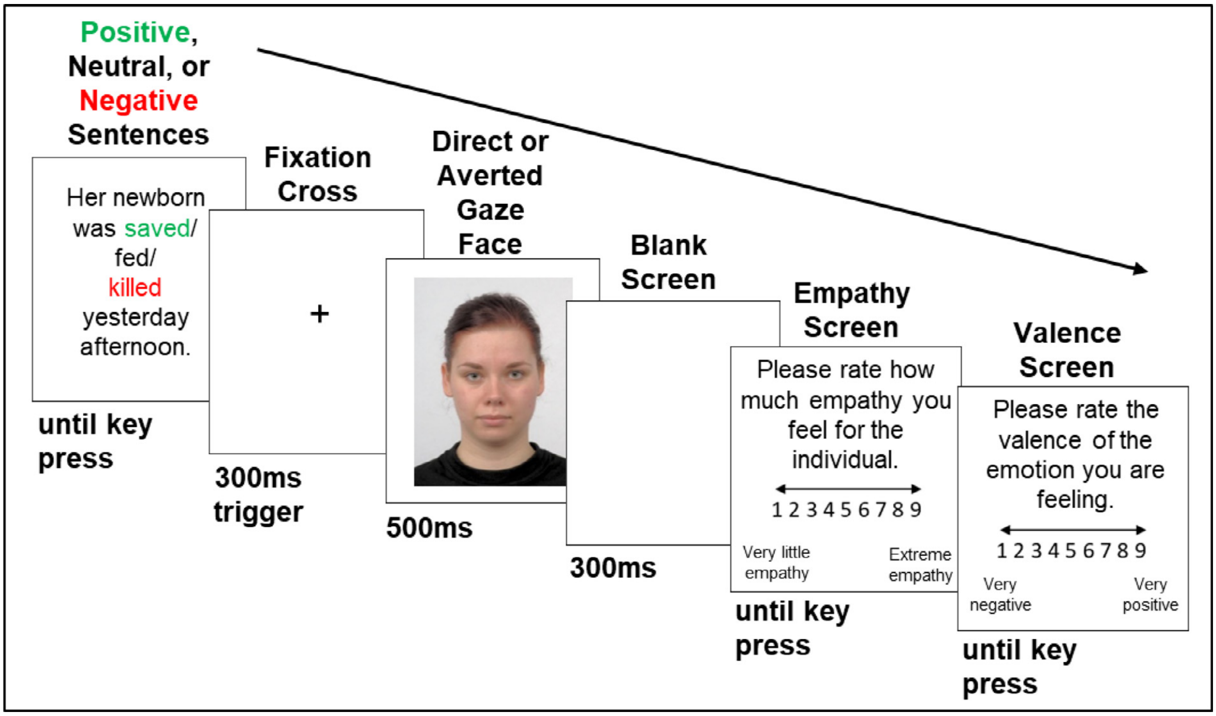

Fig. 3. Illustration of the trial progression with a direct gaze face. ERPs were time-locked to the onset of the face.

tive or no empathy (see Section 2.1). A fixation cross followed, and participants were required to fixate on the cross (within a radius of 1.92º) for 300 ms to advance the trials. If they failed to meet this requirement, a drift correction occurred and the eye-tracker was re-calibrated. If they met the requirement, they were shown a direct or averted gaze face for 500ms (13.16° horizontal by 17.49° vertical, with the eye-region subtending 5.54° horizontally and 1.39° vertically), which they were told was a picture of the person described in the sentence. Critically, the fixation cross was positioned so that participants would be looking between the nasion and the nose when the face was shown to them, ensuring that they were processing the eye-gaze. ERP recording was time-locked to the onset of the face. A 300ms blank screen followed and then two response screens appeared. The first asked participants to rate how much empathy they felt for that individual, using the number keys from 1 (very little empathy) to 9 (extreme empathy). The second asked participants to rate how positive or negative the emotion they were feeling was, from a scale of 1 (very negative) to 9 (very positive). It was further explained that for each trial, participants would read about things happening to the people they would see, and then would rate how much of their emotional state they were sharing, and the valence of the emotion they felt. An example of sharing a positive and negative emotion was provided, and participants were given the opportunity to ask for clarification.

The experiment was programmed using SR Research's Experiment Builder 1.10.1385. There were a total of 5 blocks, with 120 trials per block. For each sentence theme there were three valence conditions (positive, negative and neutral). Then within one given valence category for each sentence theme there were 8 presentations of the same sentence (half with male/female pronouns), four paired with direct gaze faces, and four with averted gaze faces. The combinations of sentence types and gaze directions meant that there were six conditions (positive direct gaze, neutral direct gaze, negative direct gaze, positive averted gaze, neutral averted gaze, negative averted gaze), with 20 trials per condition in a block, and 100 trials per condition over the course of the study. Each of the 20 face identities were shown 6 times in a block, paired with each of the six conditions. An equal number of male and female faces, as well as direct and averted gaze faces (half averted left and half averted right), were shown for each condition and block. The pronouns used in each sentence matched the face gender for that given trial. An effort was made to ensure that similar sentence themes (e.g. about dogs and cats) were not blocked together. Participants were randomly assigned to two versions of the experiment, which were created to vary which faces were presented with which sentence themes. Six practice trials were completed at the start of the experiment.

Following the computer task, participants filled out the Toronto Empathy Questionnaire (TEQ; Spreng et al., 2009), which has been shown to characterize affective empathy better than the widely used Interpersonal Reactivity Index (IRI) scale Davis (1983). The TEQ is a sixteen item self-report measure which characterizes empathy as an emotional sharing response (e.g. "When someone else is feeling excited, I tend to get excited too"). It has strong psychometric properties, with a high internal validity and test-retest reliability (Spreng et al., 2009). Scores range from 0–64, with larger scores indicating a higher degree of empathy. All but one participant completed this questionnaire (n = 43).

2.2.4. *Electroencephalography recording*

An Active-two Biosemi EEG system recorded the EEG data at 512Hz, with a Common Mode Sense (CMS) active-electrode and a Driven Right Leg (DRL) passive-electrode as the ground. Caps had 64 electrodes under the 10/20 system extended as well as electrodes PO9 and PO10 for added posterior coverage. An additional electrode was placed over each mastoid, outer eye canthus and infra-orbital ridge. Electrode direct current offset was kept within a ±20 mV range to ensure good electrode contact with the scalp.

2.2.5. *Data preprocessing and cleaning*

Eye-tracking data was used to eliminate trials in which the sentence had not been read, which we operationalized as any trial in which participants had not made at least two fixations within a rectangular region of interest spanning the text (subtending 32.71º horizontally and 3.72º vertically). An average of 5.07 trials (SD=11.04) were removed per participant as a result. In light of recent findings demonstrating that the N170 ERP component can be modulated by what part of the face is fixated (de Lissa et al., 2014; Nemrodov et al., 2014; Neath and Itier, 2015; Neath-Tavares and Itier, 2016; Itier and Preston, 2018; Parkington and

Itier, 2018), we also removed trials where participants failed to maintain fixation on the nasion and eyes (circular ROI centered on the fixation point and subtending 5.50°) for the first 250 ms of face presentation. An average of 9.57 trials (SD = 17.67) were excluded for each participant during this step.

The EEGLab (version 13.6.5b; Delorme and Makeig, 2004) and ERPLab (version 5.1.1.0; http://erpinfo.org/erplab) toolboxes were used to process the data in Matlab 2014b. The data were both average referenced and band-pass filtered (0.01–30 Hz) offline. The signal was epoched from 100 ms before face presentation (serving as a baseline) to 800ms following the face. Trials with artifacts exceeding ±70μV on any non-frontal and non-ocular channels (i.e. excluding: Fp1, Fpz, Fp2, AF3, AFz, AF4, AF8, AF7, IO1, IO2, LO1, and LO2) were removed. Independent Component Analysis (ICA; EEGLab "runica" function) was used to remove eye-blinks and lateral eye-movements picked up by frontal and ocular channels. The number of ICA components generated matched the number of channels, and an average of 1.18 (*SE* = 1.67) components were removed per participant. Any non-frontal and non-ocular channels that were consistently noisy were removed before ICA, interpolated with EEGlab's spherical splines tool and added back in after ICA. Finally, manual cleaning was used to remove any additional noisy trials, leaving an average of 59.03 (*SD* = 16.77) trials per condition in the final ERP averages (mean trial number for each condition: positive direct: 59.25 (*SD* = 16.50); positive averted: 58.43 (*SD* = 18.21); negative direct: 59.68 (*SD* = 16.33); negative averted: 58.09 (*SD* = 17.70); neutral direct: 60.43 (*SD* = 16.85); neutral averted: 58.32 (*SD* = 16.86); no Bonferroni corrected paired comparison significant).

2.2.6. Behavioural data analysis

Each participants' mean empathy and valence ratings for each condition were averaged. SPSS 25 was used to run one ANOVA with within-subjects factors of gaze direction (2; direct gaze, averted gaze) and sentence valence (3; positive, negative and neutral) on mean empathy ratings, and another on mean valence ratings. When Mauchly's sphericity test was significant, we reported the Greenhouse-Geisser corrected degrees of freedom. The raw *p*-values are reported below for all follow up paired t-tests, though please note that only those with $p < .0083$ would be considered significant with a Bonferonni correction (0.05/6 comparisons). Cohen's *d* and it's 95% confiedence interval was calculated using the free software Psychometrica.

We also investigated whether participants' self-reported trait empathy (measured by the Toronto Empathy Questionnaire- TEQ scores) correlated with how much empathy they reported during the computer task, as a way to probe the truthfulness of empathy ratings during the EEG study. For each participant we used mean empathy ratings in the computer task to calculate a positive ($\text{empathy}_{\text{positive}} - \text{empathy}_{\text{neutral}}$) and a negative ($\text{empathy}_{\text{negative}} - \text{empathy}_{\text{neutral}}$) empathy score. We also used mean valence ratings to calculate a positive ($\text{valence}_{\text{positive}} - \text{valence}_{\text{neutral}}$) and a negative ($\text{valence}_{\text{negative}} - \text{valence}_{\text{neutral}}$) valence score. We ran four correlations to see if these empathy and valence scores were correlated with TEQ scores, using a Bonferroni corrected significance threshold of $p < .0125$ (0.05/4). We reported Spearman correlations when the Shapiro-wilk normality test indicated that these variables were not normally distributed and Pearson correlations when they were.

2.2.7. EEG data analysis

The Factorial Mass Univariate Toolbox (FMUT; Fields, 2017), which is an extension of the Mass Univariate Toolbox (MUT; Groppe et al., 2011), was used to analyze our EEG data. FMUT computes tests on each time-window and electrode of interest using robust statistics and then controls for the familywise error rate. We first performed an exploratory ANOVA on all electrodes and time-points from 50ms post-face to the end of our epoch (800ms). Then, we ran ANOVAs to test our specific *a priori* time-windows and regions of interest, including ANOVAs on frontocentral sites (Fp1, Fp2, Fpz, AF3, AF4, AFz, F4, F3, F1, F2 and Fz) during the N100 (50-120ms) and the N200 (200-350ms) time windows, and on parieto-occipital sites (P9, P10, PO9. PO10, P7, P8) during the N170 (130-200ms) and EPN (200-350ms) time windows. We did not run individual ANOVAs on the LPP or P300 because our exploratory analysis had already picked up activity modulated by sentence valence spanning these components. Each omnibus ANOVA included the within-subjects factors of gaze direction (2; direct gaze, averted gaze) and sentence valence (3; positive, negative and neutral), and used an α of .05. The ANOVAs were corrected for multiple comparisons using the Permutation Based Cluster Mass technique (Maris and Oostenveld, 2007; Groppe et al., 2011), in which spatially and temporally adjacent data points are clustered together if they exceed a threshold for cluster inclusion. All *F*-values in a given cluster are then summed and compared to a null distribution of the data created by conducting 100,000 permutations. Only clusters that exceed the 1 - α percentile of the null distribution are considered significant. As discussed by Groppe et al. (2011) and Maris and Oostenveld (2007), this cluster technique is effective at picking out true ERP effects because these are more likely than noise to occur across multiple adjacent electrodes and time-points.

Follow-up ANOVAs (recommended instead of t-tests for the Permutation Based Cluster Mass technique; Fields, 2019) were conducted on significant electrodes and time-windows in the omnibus ANOVAs using Bonferroni corrected alpha levels (i.e. set to 0.016 if there were three follow-up comparisons, or 0.0083 if there were six). Again, 100,000 permutations were calculated.

3. Results

The FMUT results files and the raw behavioural data from the present study are available in the Open Science Framework Repository at the following link: https://osf.io/vkx3e/?view_only=e4d20195abdd4162ae228ffddfbf8a32.

3.1. Behavioural results

3.1.1. Empathy ratings

There was a main effect of sentence valence on participants' ratings of empathy ($F(1.39, 59.93) = 83.37$, $MSE = 211.67$, $p < .001$, $\eta p^2 = .66$; Fig. 4a). As in the sentence validation study, paired comparisons indicated that the negative condition elicited more empathy than both the neutral ($t(43) = 10.42$, $MSE = .24$, $p < .001$, $d = 1.52$ (95% CI for d [1.998,1.049])) and positive ($t(43) = 5.76$, $MSE = .12$, $p < .001$, $d = .91$ (95% CI for d [1.351,0.473])) conditions, and that the positive condition elicited more empathy than the neutral condition ($t(43) = 8.25$, $MSE = .22$, $p < .001$, d=1.35, (95% CI for d [0.885,1.811])).

There was also an interaction between sentence valence and gaze direction ($F(1.53, 65.83) = 6.12$, $MSE = .166$, $p < .01$, $\eta p^2 = .13$; Fig. 4a). Paired comparisons indicated that there was no significant effect of gaze direction on empathy ratings during negative ($t(43) = -.65$, $MSE = .057$, $p = .52$, $d = -.10$ (95% CI for d [-0.316,0.52])) or neutral conditions ($t(43) = .62$, $MSE = .039$, $p = .54$, $d = -.044$ (95% CI for d [-0.462,0.374])), but there was an effect of gaze direction during the positive condition ($t(43) = 2.76$, $MSE = .041$, $p = .008$, $d = -.41$ (95% CI for d [-0.834,0.011])). During the positive condition, participants reported feeling slightly more empathy when the faces displayed direct as opposed to averted gaze.

3.1.3. Valence ratings

There was a main effect of sentence valence on participants' valence ratings ($F(1.34, 57.77) = 129.22$, $MSE = 345.57$, $p < .001$, $\eta p^2 = .75$; Fig. 4b)[5]. Again, as in the sentence validation study, paired comparisons indicated that participants reported feeling more positive dur-

[5] Note: the four outlying points on the valence graph are from the same participant. While this participant answered unusually for the valence question, they had typical responses to the empathy questions and their TEQ score indicated

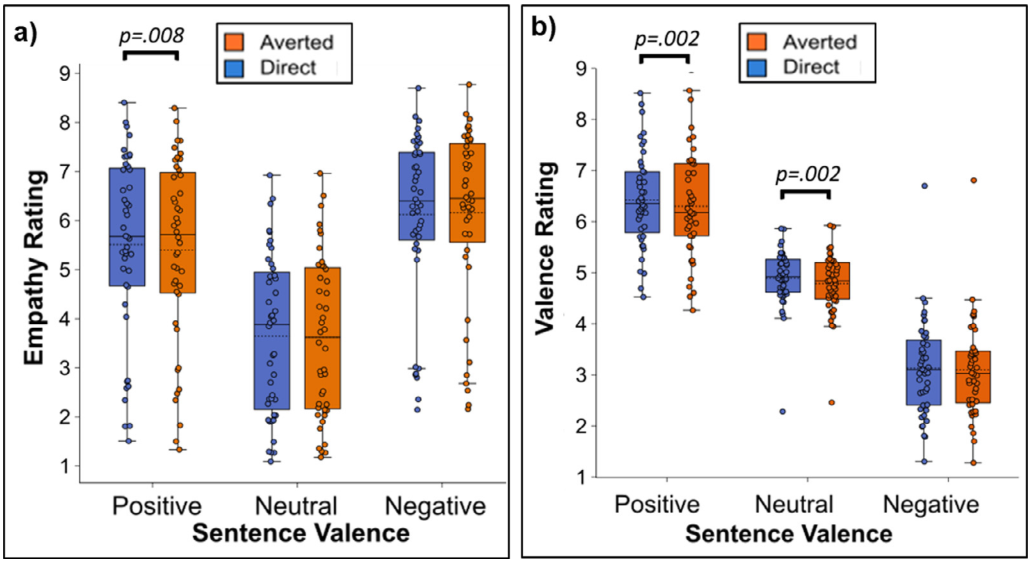

Fig. 4. a) Average *empathy* ratings for each gaze (averted, direct) and sentence valence conditions. **b)** Average *valence* ratings for each gaze and sentence valence condition. Boxes indicate data points which fall between the 25th and 75th percentiles. The mean is denoted with a dotted horizontal line and the median with a solid horizontal line. Note: Threshold for significance with the Bonferroni correction is $p<.0083$.

ing the positive condition than during the neutral ($t(43) = 12.08$, $MSE = .13$, $p < .001$, $d=1.54$ (95% CI for d [2.015,1.064])) and negative ($t(43) = 12.71$, $MSE = .26$, $p < .001$, $d = 1.87$ (95% CI for d [2.366,1.365])) conditions, as well as feeling more negative during the negative condition than during the neutral condition ($t(43) = -8.49$, $MSE = .20$, $p < .001$, $d = -3.165$ (95% CI for d [-3.792,-2.538])). There was also a main effect of gaze direction ($F(1, 43) = 11.89$, $MSE = .49$, $p = .007$, $\eta p^2 = .22$; Fig. 4b), driven by participants rating their valence as overall more positive after viewing faces with direct gaze than averted gaze. However this effect was modulated by a weak interaction between sentence valence and gaze ($F(2,86) = 3.51$, $MSE = .053$, $p = .034$, $\eta p^2 = .08$; Fig. 4b). Bonferroni corrected paired comparisons indicated that direct gaze trials were rated as more positive than averted gaze trials for the positive ($t(43) = 3.27$, $MSE = .037$, $p = .002$, $d=-.54$ (95% CI for d [-0.965,-0.115])) and neutral ($t(43) = 3.28$, $MSE = .03$, $p = .002$, $d = -.50$ (95% CI for d [-0.928,-0.079]) conditions, while there was no significant effect of gaze in the negative condition ($t(43) = 1.20$, $MSE = .027$, $p = .236$, $d=-.16$ (95% CI for d [-0.581,0.257])).

3.1.3. Relationship between behavioural ratings and self-reported trait empathy

As expected, during the experiment, participants with higher self-reported trait empathy reported experiencing stronger positive and negative empathy than participants with lower trait empathy (positive correlation between TEQ and positive empathy scores; $r_s = .503$, $p < .001$, $N = 43$; and between TEQ and negative empathy scores; $r_s = .502$, $p < .001$, $N = 43$). Participants with higher self-reported trait empathy also reported experiencing stronger positive and negative valence than those with lower trait empathy scores (positive correlation between TEQ scores and positive valence scores; $r_p = .420$, $p = .005$, $N = 43$; and between TEQ scores and negative valence scores; $r_s = -.420$, $p = .005$, $N = 43$). This manipulation check suggests that participants were accurately reporting their emotional states on each trial.

that they are likely not psychopathic. While we have kept them in because we believe they had typical empathy responses, we did try running the ERP analyses without this individual and found identical results, with the one exception being that the N200 sentence valence effect became a statistical trend instead of significant.

3.2. EEG results

3.2.1. Exploratory analysis over all electrodes (50–800 ms)

There was a widespread main effect of sentence valence, which was most pronounced over central and parietal sites (Fig. 5a; $p = .0018$) from 400-800ms (and thus encompassing the LPP and the tail end of the P300). Follow-up ANOVAs including the significant electrodes and time-points in the omnibus (IO1, LO1, F7, FT7, FC3, C1, C3, C5, T7, CP1, CP3, TP7, TP9, P1, P3, P5, PO3, PO7, O1, AFz, Cz, CPz, Pz, POz, Iz, AF8, AF4, F6, F4, F2, FT8, FC4, FC2, C4, C6, CP2, P2, P4, P6, PO4; 400-800ms) indicated that this was driven by differences between the negative and neutral conditions (Fig. 5b; $p=.00011$) and between the negative and positive conditions (Fig. 5c; $p=.0044$) over central and parietal sites. There were more positive ERP amplitudes in the negative condition than in both the neutral and positive conditions. A cluster did form for the difference between the positive and neutral conditions but it did not reach significance with our Bonferroni cut-off (Fig. 10d; $ps>.021$). There was no significant effect of gaze direction ($ps>.084$) or interaction between gaze direction and sentence valence ($ps>.42$).

3.2.2. Frontocentral sites during the N100 time-window (50-120ms)

While there was no main effect of sentence valence (no clusters found) or gaze direction ($p=.74$), there was a significant interaction between the two factors (Fig. 6a; $p=.012$). Follow-up ANOVAs (from 65-105ms; including electrodes: Fp1, Fp2, Fpz, AF3, AF4, AFz, F4, F3, F1, F2, Fz and using a stronger p value threshold of 0.016) revealed that there were main effects of gaze direction in the negative (Fig. 6b; $p=.0014$) and positive (Fig. 6c; $p=.0047$) conditions, but not in the neutral condition (Fig. 6d; no clusters found). In the negative condition, direct gaze elicited less negative ERP amplitudes than averted gaze, while the opposite pattern was seen in the positive condition.

3.2.3. Frontocentral sites during the N200 time-window (200-350ms)

There was a main effect of sentence valence (Fig. 7a; $p=.036$), which did not interact with gaze direction (no interaction clusters found). Follow-up tests (spanning 290-350ms; including electrodes: Fp2, Fpz, AF3, AF4, AFz, F4, F3, F2, Fz, p value threshold of 0.016) indicated that the N200 was larger (more negative) for the neutral condition compared to both the negative (Fig. 7b; $p=.0025$) and positive (Fig. 7c; $p=.012$) conditions. There was no difference between the positive and negative

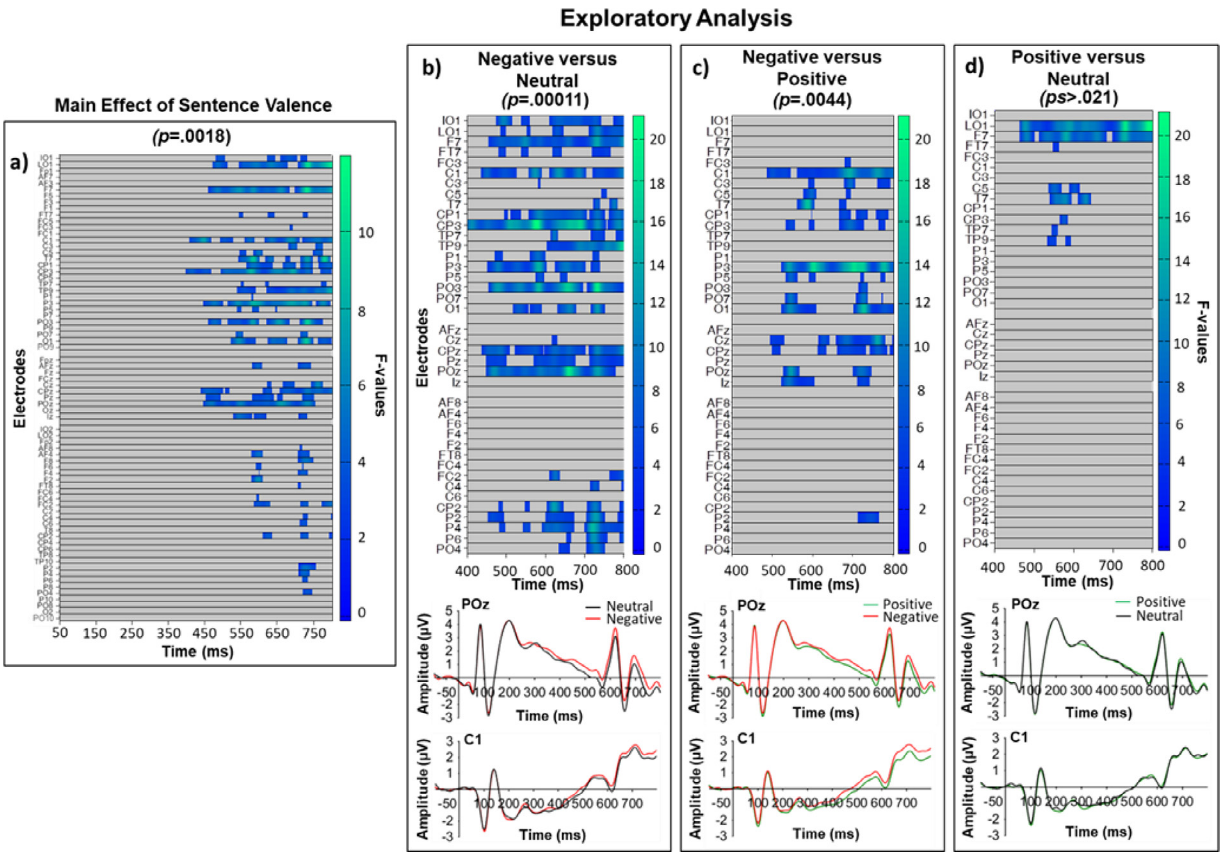

Fig. 5. **a)** Main effect of sentence valence during our exploratory analysis on all electrodes (from 50-800ms), corrected for multiple comparisons with the Permutation Based Cluster Mass technique (at p <.05 for the omnibus and p<.016 for the paired comparisons). Each electrode included in the analysis is plotted on the y-axes, while the x-axis represents time (post face onset). Coloured sections denote significant F values, as indicated by the colour bar on the right. The differences in the omnibus ANOVA were driven by differences between the **b)** negative and neutral conditions, and the **c)** negative and positive conditions, but not the **d)** positive and neutral conditions. Representative electrodes (POz and C1) are shown for each paired comparison.

conditions (Fig. 7d; p=.38). There was no main effect of gaze direction (p=.38).

3.2.4. Posterior sites during the N170 time-window (130-200 ms)

There was a right-lateralized main effect of gaze direction from approximately 150–195 ms (Fig. 8, p = .011; P10, P08, PO10), driven by more negative ERP amplitudes for averted gaze than direct gaze. While this effect was picked up during the N170 time-window, it occurred after the N170 peak, on the ascending part toward the P200. There was no main effect of sentence valence (p = .33), nor an interaction between sentence valence and gaze direction (p = .52).

3.2.5. Parieto-occipital sites during the EPN time-window (200–350 ms)

There was a main effect of sentence valence restricted to the right hemisphere (Fig. 9a; p=.036). Follow-up ANOVAs (from 300-350ms, including P8, P10, PO8) indicated that this was driven by more negative-going ERP amplitudes in the negative condition than in the neutral condition (Fig. 9b; p=.000020). Although it did not meet our Bonferroni corrected cut-off, there was a similar trend for more negative-going ERP amplitudes in the positive than in the neutral condition (cluster significance of p=.021; Fig. 9c). There was no difference between the negative and positive conditions (Fig. 9d, no clusters found).

While there was no main effect of gaze direction (p=.32), there was an interaction between gaze and sentence valence restricted to the left hemisphere (Fig. 10a; p=.020). Follow up comparisons (from 200-275ms, including P7, P9, PO7) indicated that there were more positive amplitudes for direct gaze than averted gaze in the positive condition (Fig. 10c; p=.0050), while there was no difference between direct and averted gaze in the negative (Fig. 10b; no clusters found) or neutral (Fig. 10d; p=.060) conditions. While the interaction occurred during the time window analysed to encompass the EPN, visual inspection of the waveforms indicated that it occurred earlier than the main effect of valence, and was a modulation of the P200 ERP component (Fig. 10).

4. Discussion

There is evidence to suggest that processing eye-gaze impacts our theory of mind (Baron-Cohen and Cross, 1992) and our emotional state (e.g. Nichols and Champness, 1971; Conty et al., 2010; McCrackin and Itier, 2018a; Baltazar et al., 2014). However, it is still unclear how the perception of eye-gaze may impact our ability to affectively empathize with the gazer, that is, to share in their emotional state. In the present study, we asked participants to rate how much they affectively empathized with direct and averted gaze individuals who had experienced positive, neutral and negative scenarios. We predicted that, because the perception of direct gaze is associated with emotional (Nichols and Champness, 1971; Conty et al., 2010; McCrackin and Itier, 2018a; Baltazar et al., 2014) and self-referential (see Conty et al., 2016) processing and mimicry (Wang et al., 2010), which seem important for experiencing empathy (Lieberman, 2007; Joireman and Hammersla, 2002; Sonnby-Borgström, Jönsson, and Svensson, 2003), participants would report feeling more affective empathy for individuals displaying direct gaze than averted gaze.

We found that participants reported experiencing slightly more affective empathy for characters with a direct compared to an averted gaze,

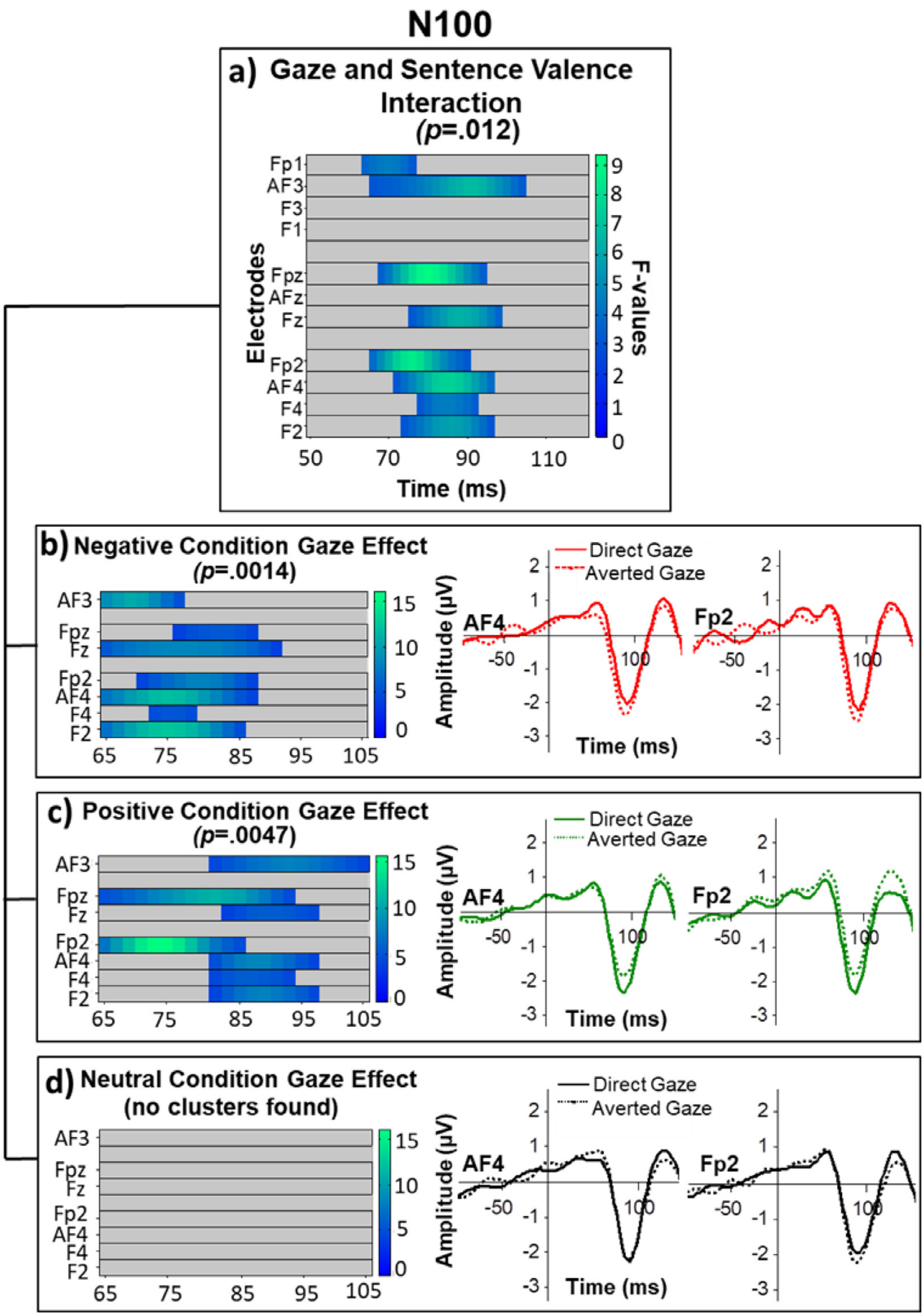

Fig. 6. **a)** Gaze direction and sentence valence interacted in the N100 time window (50-120ms). Time post-face onset is denoted on the x-axis, and electrodes are listed on the y-axis. Coloured sections correspond to the significant *F* values as indicated by the right-hand colour bar and corrected for multiple comparisons using the Permutation Based Cluster Mass technique (p <.05 for the omnibus ANOVA, p<.016 for post-hoc paired comparisons). As can be seen on representative electrodes (AF4 and Fp2), there was a significant effect of gaze direction in the **b)** negative and **c)** positive conditions, but not in the **d)** neutral condition.

but only when these characters had experienced positive scenarios. They also reported slightly more positive valence in response to characters with direct compared to averted gaze during positive and neutral trials, but not during negative trials. These effects cannot be attributable to the slight habituation elicited by sentence repetition (see endnote for details). While these behavioural effects were small, we should emphasize that they were detectable with just 500ms presentations of face images, a timing chosen to reduce eye-movements (which would contaminate the EEG signal) and trial duration (which would make the whole study too long). It is possible that eye-gaze had an effect in this study because it was one of the only physical cues that varied between each trials (besides gender and identity). However, as several studies have suggested

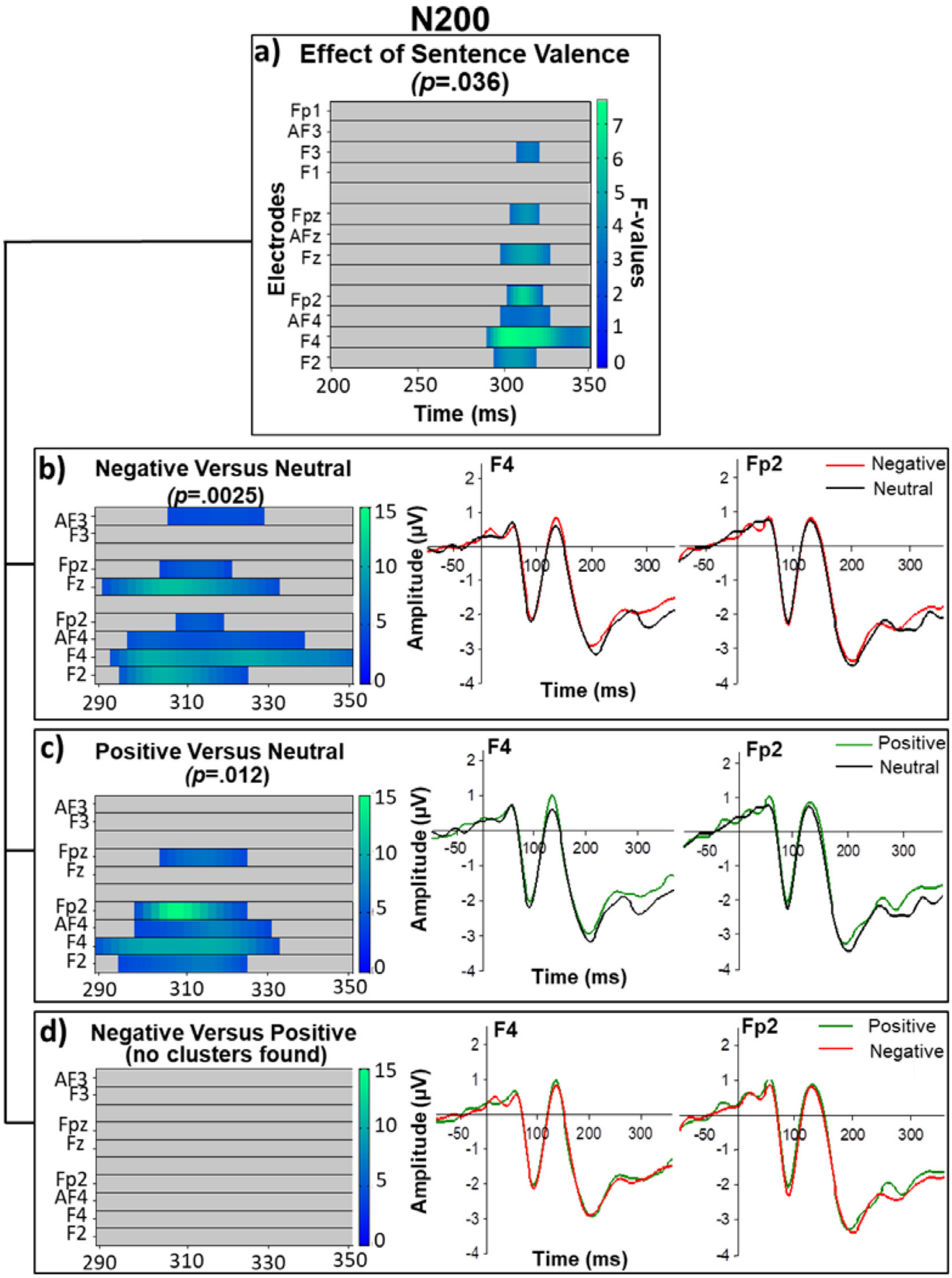

Fig. 7. **a)** Sentence valence modulated fronto-central N200 (200-350ms) ERP amplitudes. The Permutation Based Cluster Mass technique was used to correct for multiple comparisons, at $p < .05$ (and at $p < .016$ for the post-hoc comparisons). Electrodes are plotted on the y-axis, and time post-face onset is plotted on the x-axis. Time points and electrodes with significant effects are denoted with coloured blocks, and the magnitude of significance is denoted by colour bar on the right. There were significant differences between the **b)** negative and neutral conditions and the **c)** positive and neutral conditions, but not between the **d)** negative and positive conditions. Representative electrodes (F4 and Fp2) are shown.

that live actors can increase the cognitive impact of face (Tuefel et al., 2010) or gaze cues (e.g. Pönkänen et al., 2010; Hietanen et al., 2008; Pönkänen et al., 2011), this gaze effect may be larger with real people, especially given the social nature of empathy. The gaze effects might also be different if the face was expressing an emotion congruent with the sentence context. For instance, one could imagine that direct gaze might impact empathy in the negative condition if the face was also expressing sadness. These possibilities will have to be tested empirically in the future.

Our findings add to a growing literature suggesting that the effects of direct gaze perception on various face processing tasks are context specific Hamilton (2016). Indeed, while perceiving direct gaze has been previously associated with increased positive valence relative to averted gaze McCrackin and Itier (2018), here we found that direct gaze was

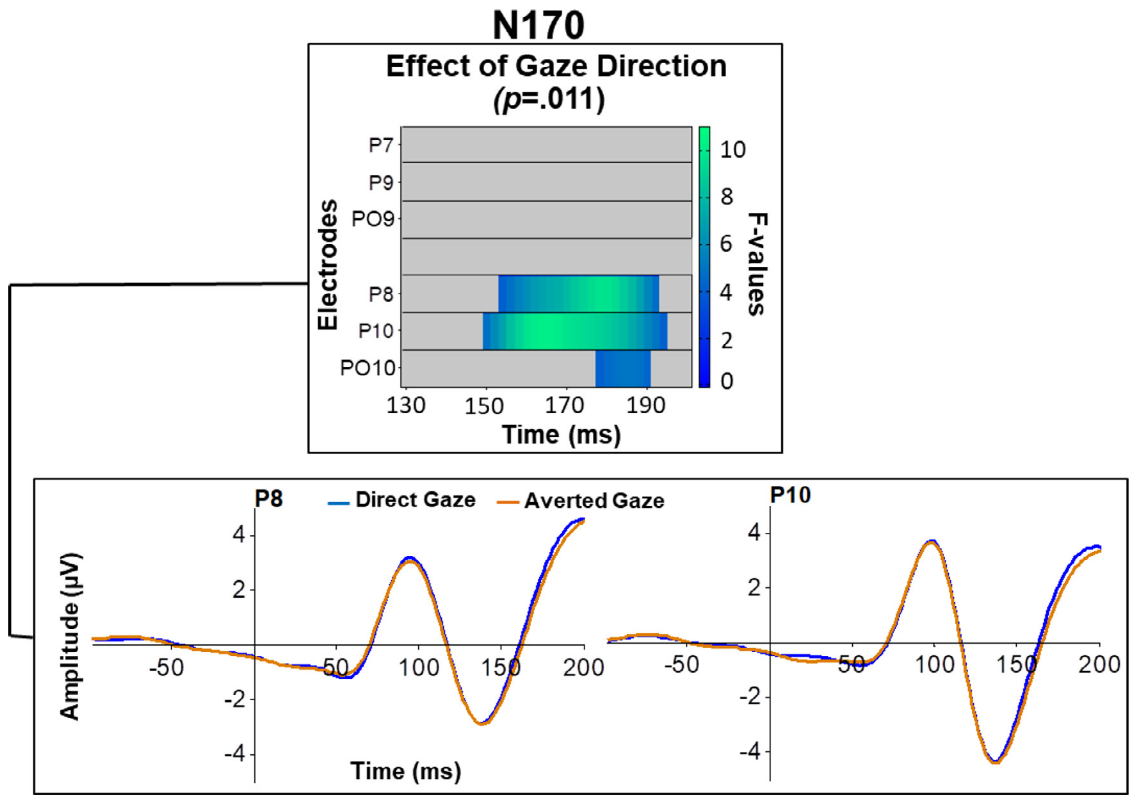

Fig. 8. An analysis of the N170 time-window (130-200ms) revealed that gaze direction had an effect on the ascending part from the N170 peak toward the P200, over right sites only. Direct gaze was associated with less negative ERP amplitudes, as shown on representative electrodes (P8 and P10). The Permutation Based Cluster Mass technique for multiple comparisons was applied at $p < .05$. Electrodes are indicated on the y-axis, and time post-face onset is indicated on the x-axis. Significant electrodes and time-points are indicated with coloured blocks corresponding to the right-hand colour bar.

not associated with increased positive valence in the negative condition. Against our predictions, direct gaze was also not associated with increased affective empathy in the negative condition, leading us to conclude that direct gaze may only facilitate affective empathy and positive valence in positive contexts (when the face is of neutral expression). Another possibility is that there is a smaller impact of eye-gaze in negative context, which may only be picked up with longer stimulus presentation times, an interesting idea that could be tested by follow-up studies.

We believe the present study is one of the first examinations of how the time-course of positive and negative affective empathy may differ (see Morelli, Lieberman and Zaki 2015, for a review). As with all ERP research, there is a temptation to assume that the ERP activity elicited by a given task is specific to that task (Amodio et al., 2014). However, as Amodio et al. (2014) explained, the modulation of ERPs reflects activity that is likely common to many tasks. In the present study, our affective empathy task modulated ERPs typically associated with emotional processing in different types of emotional tasks. We have drawn parallels between the ERP activation in our affective empathy task and other affective tasks in an attempt to elucidate how affective empathy works, and what these ERP components reflect. We interpret these components here as precursors to the subjective affective empathy ratings that participants provided at the behavioural level.

We found early (290–350 ms) commonality in how positive and negative affective empathy were processed, with both positive and negative trials eliciting less negative ERP amplitudes than neutral trials over the fronto-central N200 component. It is unclear where this frontal activity stems from, but one possibility is the prefrontal cortex, which is associated with both positive and negative affective empathy (Mobbs et al., 2009; Morelli, Sacchet, and Zaki, 2015, Light et al, 2009; Balconi and Vanutelli, 2017). Similar N200 modulation has been theorized to reflect an initial automatic activation of emotion areas (Fan and Han, 2008), potentially through mirror neuron system activation (Gallese & Goldman, 1998). However, this theory stems primarily from nociceptive empathy studies, in which ERPs elicited by pain-inducing stimuli are compared to those elicited by neutral stimuli. The present study's results suggest that, when using face pictures primed by situational sentences, N200 modulation occurs for both positive and negative stimuli, and more importantly, can occur in response to the exact same physical stimuli (neutral faces) placed into different affective contexts. However, we should also note that while we found the N200 to be modulated by our empathy task, a recent meta-analysis indicated that the link between the N200 and empathy is unclear Coll (2018). More mass univariate analyses are needed to investigate the impact of empathy on frontal sites during this time-window.

We then found divergence between positive and negative trials at later processing stages. The EPN, P300 and LPP components appeared to be modulated specifically by negative affective empathy. Indeed, there were more negative EPN amplitudes during negative trials relative to neutral trials from 300–350 ms over the right hemisphere, with no difference between positive and neutral trials. There were also more positive ERP amplitudes over frontal, central and centroparietal sites during negative relative to both neutral and positive trials from 400-800ms, spanning the end of the P300 and the LPP components. Although these modulations could reflect differences in negative versus positive affective empathy, perhaps due to activation of negative or positive emotion centres, this possibility is unlikely given the lack of amplitude difference between positive and neutral trials. Alternatively, these later stages of processing might reflect the experience of empathic concern, which is a facet of empathy distinct from affective sharing (Decety et al. 2015). Decety et al. (2015) found that the LPP amplitude difference between painful and neutral stimuli was positively correlated with trait empathy and negatively correlated with psychopathic traits during their em-

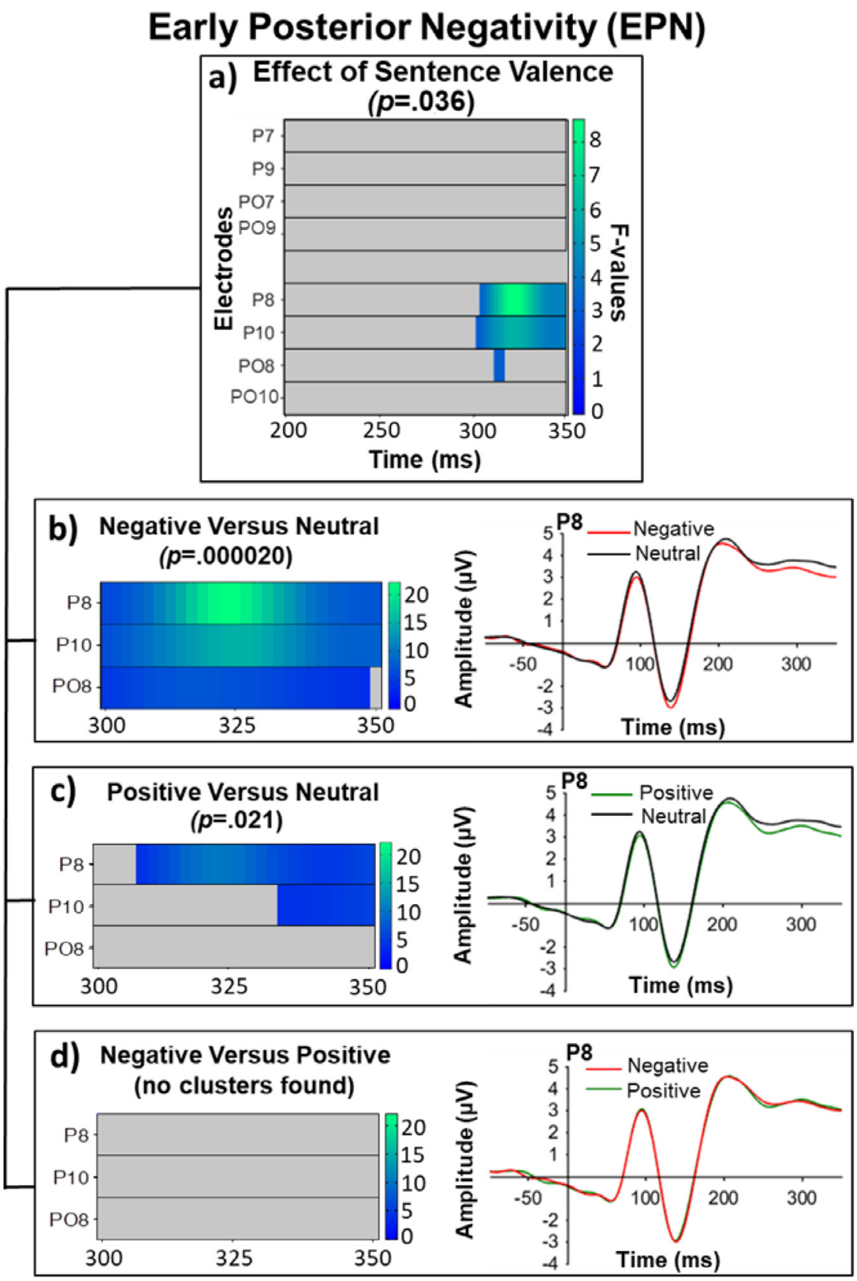

Fig. 9. a) Sentence valence modulated parieto-occipital ERP amplitudes during a restricted portion of the EPN time-window (significant during 300-350ms) but only on the right hemisphere. Note that all faces had neutral expressions, so the effect was uniquely driven by the valence of the contextual sentence. The Permutation Based Cluster Mass technique was used to correct for multiple comparisons, at p <.05 (and at p<.0083 for the post-hoc comparisons). Each electrode is plotted on the y-axis, with time following the face onset on the x-axis. Coloured sections correspond to significant F values, as denoted by the right hand colour bar. The main effect in the omnibus ANOVA was driven by differences between the **b)** negative and neutral conditions, but not the **c)** positive and neutral or **d)** negative and positive conditions. A representative electrode (P8) is shown.

pathic concern task but not during their affective sharing task. Thus, it is possible that these later components may reflect processing related to empathic concern, which would likely be present in our negative condition, but not in our positive one. Moreover, although our behavioural data indicated that negative trials did elicit slightly more affective empathy than positive trials, positive trials also elicited more empathy than neutral trials, ruling out the possibility that these larger LPP amplitudes for negative trials be solely due to the magnitude of empathy as opposed to its valence.

While the EPN to faces is traditionally modulated by facial expressions (e.g. Neath and Itier, 2015; Neath-Tavares anf Itier, 2016; Itier and Neath-Tavares, 2017; Schupp et al., 2004; Schupp et al., 2006; Schact and Sommer, 2009; Rellecke et al., 2012), it should be emphasized again that all of the face stimuli here were neutral. The only change across trials was the context provided before the face, which aligns with recent research demonstrating that the EPN and LPP to both neutral faces (Weiser et al., 2014; Weiser and Moscovitch, 2015; McCrackin and Itier, 2018; Klein et al., 2015) and emotional faces (Dieguez-Risco et al., 2013; 2015; Aguado et al., 2019) can be modulated by affective context. The EPN is thought to be modulated by emotional stimuli due to attentional or arousal effects while the modulation of the LPP by emotional stimuli may reflect the cognitive appraisal of the emotional stimuli.

We also found support for the association between eye-gaze and positive empathy at the neural level. The frontal N100 ERP component is believed to be modulated by an automatic activation of frontal emotion areas in an observer Fan and Han (2008). Accordingly, gaze direction did not modulate the N100 during neutral (i.e. low empathy) trials, but did so during the trials designed to elicit empathy. During positive trials, direct gaze elicited more negative N100 amplitudes than averted gaze, while the opposite was seen during negative trials, with direct gaze eliciting less negative amplitudes. Again, our visual stimuli were all neutral faces, as opposed to the traditional nociceptive stimuli used by Fan and Han (2008). In our paradigm, there was nothing innately emotional about the stimuli themselves. During the time of visual pre-

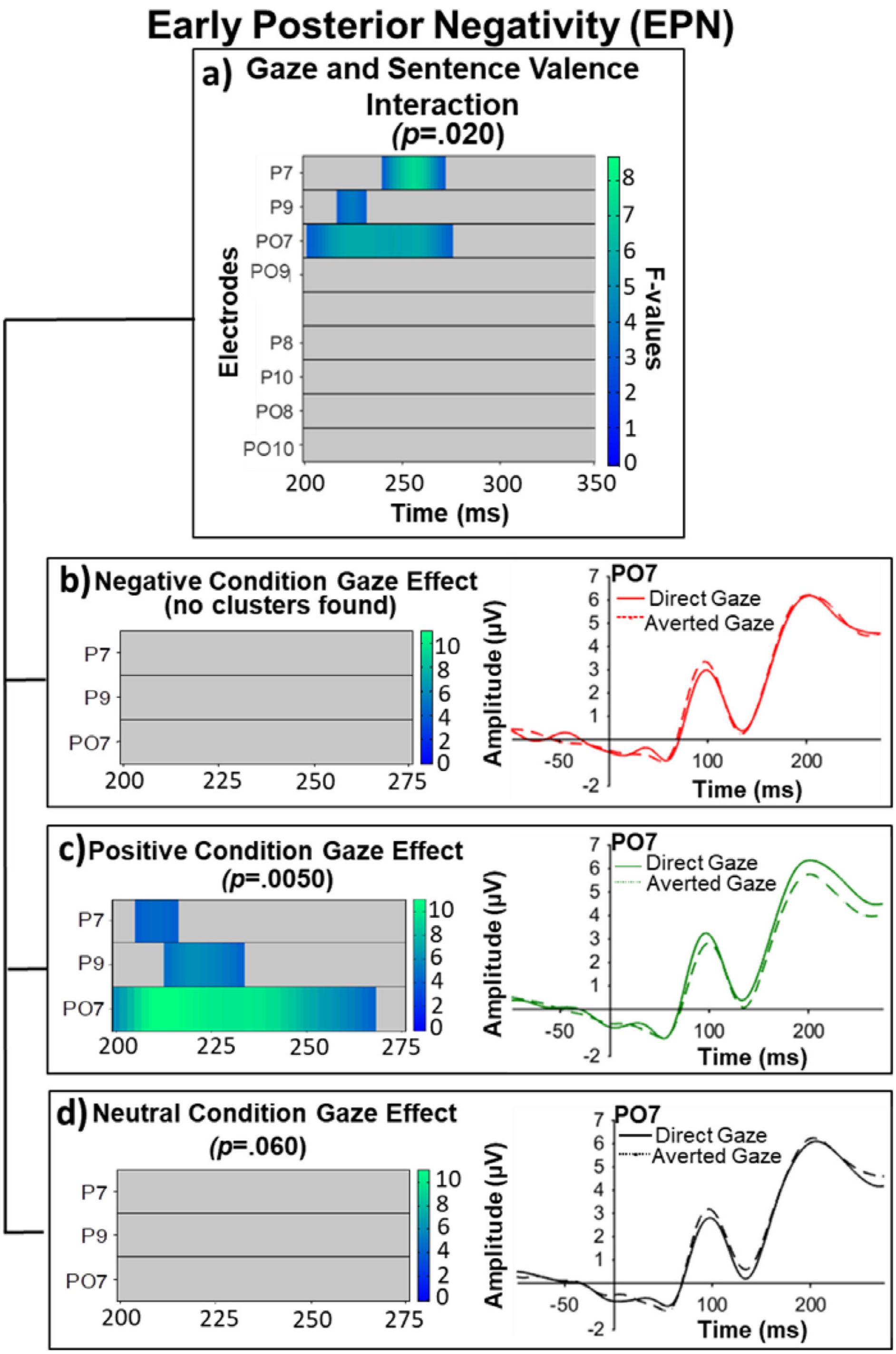

Fig. 10. a) Gaze direction interacted with sentence valence during the portion of the EPN time-window analyzed corresponding to the P2 component (significant between 200-275ms) but only over the left hemisphere. Electrodes are plotted on the y-axis, with time post-face onset on the x-axis. Coloured sections correspond to significant *F* values, as denoted by the right-hand colour bar and corrected for multiple comparisons using the Permutation Based Cluster Mass technique ($p < .05$). Follow up comparisons (using $p < .0083$) indicated that there was a significant effect of gaze direction in the **c)** positive condition, but not in the **b)** negative or **d)** neutral conditions, as can be seen on a representative electrode (PO7).

sentation in the present study, the emotional context had already been instated, and this may have acted to prime the frontal activation that we observed here, perhaps through top-down modulation. This early instatement of the emotional context may also explain why the frontal activation that we report is earlier (65-105 ms) than the frontal activation reported by Fan and Han (2008; 140–180 ms). However, as for the N200, these N100 results should be replicated with robust statistics.

We also found that gaze direction modulated later ERP amplitudes during only positive trials over the left hemisphere, with more negative amplitudes for averted than direct gaze. While this modulation was detected during our EPN analysis, its timing corresponded to the P200 component. The P200 gaze modulation during only positive trials may be related to the unique behavioural interaction between gaze direction and positive empathy ratings. The P200 is the fifth most commonly analysed ERP component in paradigms designed to evoke empathy. It has shown previous modulation by empathy (Coll et al., 2018) and appears to be modulated more during an affective sharing task than during an empathic concern task (Decety et al., 2015). Previous research has shown that the P200 is more positive in response to pleasant stimuli, but not negative stimuli (see Olofsson et al., 2008 for a review), which aligns with our finding of more positive ERP amplitudes for direct gaze than averted gaze during positive contexts. The P200 also occurs at approximately the same time as the frontal N200 (Olofsson et al., 2008), so it is possible that the neural generators of these components are part of a larger interactive network responsive to the emotional feeling triggered by affective empathy and by direct gaze.

Both our behavioural and ERP findings provide support for the idea that direct gaze and positive empathy may functionally overlap, and it is important to consider what the mechanism behind this overlap may be. We initially theorized that because direct gaze is associated with self-referential processing (Conty et al., 2016; Kampe et al., 2003; Pönkänen, Peltola, and Hietanen, 2011; Hamilton, 2016), it may facilitate an individual's ability to affectively empathise by allowing them to better simulate the emotion within themselves (Lieberman, 2007; Joireman and Hammersla, 2002; but see Boyraz and Waits, 2015 for null results). However, this theory does not seem to hold in view of the result that direct gaze facilitated positive, but not negative, empathy. We also hypothesized that direct gaze might facilitate empathy due to shared activation of emotional processing areas. This idea shows more promise due to the link between direct gaze and reward system activation (see Hietanen 2018 for a review). Increased ventral striatum activation is not seen for negative empathy and seems unique to positive empathy (Mobbs et al., 2009); the ventral striatum is also implicated in positive affect and reward processing (Cardinal et al., 2002; de la Fuente-Fernández et al. 2002; Schreuders et al. 2018), and is a neural correlate of perceiving direct gaze (Strick et al., 2008; Kampe et al., 2001). The interaction between gaze and trial valence on the P200 component was also left-lateralized, and left lateralization of positive emotions (see Machado and Cantilino, 2017 for a review) and positive empathy (Balconi and Vanutelli, 2017) has been previously observed. We therefore suggest that direct gaze processing and positive empathy functionally overlap due to shared neural correlates involved in the experience of positive emotion.

The use of a lab task instead of a live actor is one limitation of this study, and future research should investigate whether these findings generalize to real life situations. It would also be interesting to see if the results would differ if the described individuals uttered the statements themselves. We believe that what matters here is that the gazing person is the person portrayed in the situation, and thus they are the subject of the situation. However, this would need to be empirically tested in a modified paradigm. Another important limitation is the assumption that participants understood the task correctly and accurately reported their emotional state. However, we believe they were accurate based on the correlations between TEQ and empathy ratings, and given that there were parallels between the behavioural and ERP eye-gaze effects. Our trial repetition analysis (see endnote) provides further support for correct reporting, given that participants did seem to become slightly desensitized to the trials as they repeated, as would be expected if participants were accurately reporting their emotions.

Finally, we found no evidence that the N170 itself was being modulated by eye-gaze during this task, though a small effect of gaze was seen on the ascending part toward the P200 at right lateralized sites. The N170 gaze effect has been proposed to be due to changes in luminance and contrast that occur during the perception of dynamic gaze stimuli (e.g. Conty et al. 2007; see Puce et al. 2015 for a review). The lack of N170 effects here would fit with this idea, given that all direct and averted gaze comparisons were between static images. However, other groups have reported N170 gaze effects with static face pictures (Itier et al., 2007; Watanabe et al., 2002; Burra et al., 2017), so it is still unclear if those effects may have been driven by individual differences in each sample, or methodological differences like ERP analysis techniques, task demands, or fixation location on the face (see McCrackin and Itier, 2019 for more discussion on these points). All we can say at present is that in this empathy task where static face pictures were used whose gaze direction was task-irrelevant, gaze did not affect the N170 amplitude.

In conclusion, we found support for the idea that positive and negative empathy elicit different behavioural and neural correlates, follow different time courses and interact with the gaze direction of the person we empathize with in subtle ways. Positive and negative trials were processed similarly at the early N200 processing stage, while only negative trials modulated the EPN, P300 and LPP components. The early commonality may reflect the activation of emotion areas during affective sharing, while the later differences may be driven by the empathic concern specific to negative trials. Negative and positive empathy were associated with differential processing of direct and averted gaze before and during the N100 time window, which may reflect top-down modulations linked to the affective sharing component of empathy. Positive empathy was also associated with differential processing of eye-gaze during the P200 time window, which might relate to the finding that participants reported feeling slightly more positive empathy after perceiving direct gaze. These results suggest that perceived gaze direction impacts our ability to share in another's emotional state, highlighting the importance of studying empathy in the context of faces. The current paradigm may also be of use in research with special populations, in which there are differences in both eye-gaze processing and empathy, like social anxiety disorder (e.g. Schmitz et al., 2012; Morrison et al., 2016) and psychopathy (e.g. Dadds et al., 2008; Dadds et al., 2012; Gillespe et al., 2015). The present study was performed in neurotypical individuals, but the link between eye-gaze and empathy processing in special populations warrants further research.[6]

Data availability statement

The FMUT results files and the raw behavioural data from the present study are available in the Open Science Framework Repository at the following link: https://osf.io/vkx3e/?view_only=e4d20195abdd4162ae228ffddfbf8a32.

Declaration of Competing Interest

We report no potential conflicts of interest.

Credit authorship contribution statement

Sarah D. McCrackin: Conceptualization, Methodology, Software, Formal analysis, Data curation, Writing - original draft, Writing - re-

[6] As each sentence theme was shown 4 times for a given valence and gaze condition, we also averaged each participant's empathy and valence ratings for each of the four presentation times and re-ran the ANOVA with factors of Valence (3: positive, negative, neutral), Gaze Direction (2: direct, averted) and Trial Repetition (1, 2, 3, and 4 repetitions) with an average of 20.06 (SD = 4.11) trials per condition. There was a main effect of trial repetition on empathy ratings ($F(1.67, 71.91) = 14.59$, MSE = .25, $p < .001$, $\eta p^2 = .25$), modulated by a trial repetition and sentence valence interaction ($F(4.43, 190.36) = 3.53$, MSE = .17, p =.003, $\eta p^2 = .076$). Participants reported slightly lower empathy as trials repeated, for negative (p<.001, $\eta p^2 = .22$), positive (p=.004, $\eta p^2 = .18$) and neutral trials (p=.011, $\eta p^2 = .082$). The decrease was slightly larger for negative trials than both positive trials (p=.023) and neutral trials (p=.013), which did not differ but came close (p=.051). There was also a main effect of trial repetition on valence ratings ($F(2.27, 97.67) = 3.36$, MSE = .110, p =.033, $\eta p^2 = .072$), again modulated by a trial repetition and sentence valence interaction ($F(4.32, 185.59) = 12.48$, MSE = .17, $p < .001$, $\eta p^2 = .23$). In the positive (p<.001, $\eta p^2 = .25$) and neutral conditions (p=.027, $\eta p^2 = .068$), valence generally decreased with increasing trial repetition, while in the negative condition (p=.008, $\eta p^2 = .10$), valence increased with trial repetition (i.e. becoming less negative). These results suggest that repeated exposure to the situational context decreased its effect on participants' feelings of empathy, though the effects were quite small and do not change our interpretation of the findings. There were no trial repetition and gaze direction interactions (empathy ratings: p=.080, $\eta p^2 = .055$; valence rating: p=.39, $\eta p^2 = .023$), nor trial repetition, sentence valence, and gaze direction interactions (empathy rating: p=.62, $\eta p^2 = .015$; valence rating: p=.067, $\eta p^2 = .048$), suggesting that the mild desensitization upon repeated exposure did not impact eye-gaze effects or interactions.

view & editing, Visualization, Project administration, Funding acquisition. **Roxane J. Itier:** Supervision, Conceptualization, Methodology, Writing - review & editing, Funding acquisition, Resources.

Acknowledgements

We would like to thank Amie Durston, Michelle Lee, Jenna Singleton Sonoski and Taylor Jarvis for their help putting the EEG cap on participants. We would also like to thank Mariem Hamdy for her help with both EEG capping and with scoring the questionnaires. Finally, we would like to thank Michelle Prince for her help processing the behavioural data.

Funding

This work was supported by a Queen Elizabeth II Graduate Scholarship for Science and Technology (QEII-GSST) awarded to SDM and by grants from the Natural Sciences and Engineering Research Council of Canada (NSERC Discovery Grant #418431), the Canada Foundation for Innovation (CFI, #213322), and the Canada Research Chair program (CRC, #230407), awarded to RJI.

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