Effect of empathy trait and gender on attention to face

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PhD thesis

Effect of empathy trait and gender on attention to face

共感特性と性別が顔に対する注意反応に及ぼす影響

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February 2015

Declaration

I hereby declare that this dissertation entitled “Effect of empathy trait and gender on attention to face” is not substantially the same as any that I have submitted for a degree or diploma or other qualification at any other University.

Those parts of this thesis which have been published are as follows:

1. Chapter 2 is based on the paper “**Effect of empathy trait on attention to faces: an event-related potential (ERP) study** (Choi D, Watanuki S, J Physiol Anthropol 2014, 33:1)”.

2. Chapters 4 is based on the paper “**Effect of empathy trait on attention to various facial expressions: Evidence from N170 and late positive potential (LPP)** (Choi D et al., J Physiol Anthropol 2014, 33:18)”.

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Chapter 1
Background

1.1 Introduction

Humans are considered social animals, as they have greater and more extensive social cognitive abilities than many other species (Gazzaniga, 2008). To achieve amicable social interactions, it is important for humans to pay attention to the faces of other humans and to discriminate facial expressions accurately. However, attention response to faces is thought to differ depending on characteristics of individuals such as personality and gender.

Given that the face provides such important cues to understanding the emotions and ideas of others, attention response to faces is thought to be deeply related to empathy. Previous neuroscience studies have suggested that facial expressions play an important role in empathic responses (Carr et al., 2004; Leslie et al., 2004; Schulte-Rüther et al., 2007). For example, in a functional magnetic resonance imaging (fMRI) study by Carr et al. (2003), imitation and observation of facial expressions activated largely overlapping brain areas (for example, the insula), suggesting that empathy is related to action representation such as imitation of the facial expressions of others. Thus, one factor causing individual differences in attention response to faces is thought to be the empathy trait of individuals. Indeed, some neuroscience studies have reported relationships between empathy trait and brain activities evoked by watching faces (for details, see 1.2.2 Relationship between empathy trait and brain activity).

In order to extend the knowledge of individual difference in attention response to faces, this thesis aimed to investigate effect of empathy trait on attention to faces. To do so, I conducted two experiments and examined attention responses elicited by discrimination of facial expressions. In those two experiments, event-related potential (ERP) was measured as index of attention (for details, see 1.2.3 Event-related potential (ERP)). Empathy trait of individuals was measured by using Interpersonal Reactivity Index (IRI) questionnaire (Davis, 1980) (for details, see 1.2.1 Empathy).

Furthermore, gender is also important factor of individual difference in attention to faces. Many neuroscience studies have reported that brain activity elicited in response to human faces differs between males and females (for details, see 1.2.4 Gender difference in attention to faces). However, it is still unclear whether there is gender difference in attention to faces even when empathy trait does not differ between genders. Thus, this thesis also aimed to investigate gender difference in attention to faces, by reanalyzing data from two experiments mentioned above.

1.2 Review of literature

1.2.1 Empathy

Empathy is defined as 'the ability to imagine oneself in another's place and understand the other's feelings, desires, ideas, and actions (Encyclopedia Britannica, 1999 edition)'. Empathy lets the individual understand another person's emotions, such as pain, and to act altruistically toward that person (Davis, 1995). Empathy also enables individuals to put themselves in the other person's position, and to predict how they might act (Smith, 2006). Some animals (for example, chimpanzees and dogs) also can take perspective of others; however, humans have more sophisticated and extensive empathy ability (Gazzaniga, 2008). Empathy is thus an essential ability required for social activities of human being.

Individual differences exist in the empathy trait. In other words, sensitivity to sharing the emotions of others and the willingness to consider the positions of others vary among individuals. The reason why individual differences exist in empathy trait might be that the ability and methods to adapt to social environments differ depending on the individual. As mentioned above, the empathy ability of humans appears relatively sophisticated (Gazzaniga, 2008) and human social interactions are also complex. The complexity of human social interactions might thus cause individual differences in empathy trait.

Numerous studies have developed questionnaires to measure these individual differences in empathy trait. Some examples are the Interpersonal Reactivity Index (IRI) (Davis, 1983), Empathy- and Systemizing quotient (EQ-SQ) (Baron-Cohen et al., 2003; Baron-Cohen & Wheelwright, 2004), and the Balanced Emotional Empathy Scale (BEES) (Mehrabian & Epstein, 1972). Among these questionnaires, the IRI (Davis, 1983) is widely used to measure the empathy trait not only in psychology, but also in neuroscience (for example, Jabbi et al., 2007; Singer et al., 2004; Hooker et al., 2008; Krämer et al., 2010; Soria Bauser et al., 2012).

The IRI comprises four empathy subscales: perspective taking; fantasy; empathic concern; and personal distress (for details of subscales, see Table 1.1). According to a recent review of empathy (Zaki & Ochsner, 2012), empathy has three facets: sharing of experience (which is sharing another's state); mentalizing (which is considering and understanding another's state); and prosocial concern (which is expressing motivation to help another). The IRI subscales are thought to reflect those three facets of empathy. In other words, personal distress and fantasy scales of IRI appear to reflect the sharing of experience facet of empathy, whereas perspective taking scale of IRI appears to reflect the mentalizing facet of empathy. Empathic concern scale of IRI appears to reflect the prosocial concern facet of empathy. Thus, IRI is thought to be an appropriate index for measurement of empathy trait of individuals.

Table 1.1 Subscales of IRI

Subscales	Trait to be measured
Perspective taking	Attempts to take the perspectives of others (e.g., I try to look at everybody's side of a disagreement before I make a decision)
Fantasy	Tendency to identify with fictitious characters (e.g., After seeing a play or movie, I have felt as though I were one of the characters)
Empathic concern	Tendency to feel warmth and compassion for others (e.g., I often have tender, concerned feelings for people less fortunate than me)
Personal distress	Discomfort elicited by observing the negative experiences of others (e.g., Being in a tense emotional situation scares me)

1.2.2 Relationship between empathy trait and brain activity

It has been reported that brain activity from stimuli containing human figures differs between people with high and low empathy trait (measured using IRI, EQ, and BEES) by numerous neuroscience studies including fMRI studies (Jabbi et al., 2007; Singer et al., 2004; Hooker et al., 2008; Krämer et al., 2010; Chakrabarti et al., 2006), ERP studies (Soria Bauser et al., 2012), and EEG (Electroencephalography) study (Choi & Watanuki, 2012).

For example, in fMRI study by Singer et al. (2004), participants experienced a painful stimulus and observed their partner receiving a similar pain stimulus. They filled out IRI (Davis, 1983) and BEES (Mehrabian & Epstein, 1972) in order to measure their empathy trait. The result showed that IRI and BEES scores of participants correlated positively with activation of anterior cingulate cortex and insula elicited by observing their partner receiving pain stimulus (Singer et al., 2004). In addition, in fMRI study by Jabbi et al (2007), participants observed the facial expressions (pleasant, unpleasant, and neutral) of others and filled out IRI (Davis, 1983). The results showed that participants with higher IRI, compared with those with low IRI, showed greater activation of the anterior insula and frontal operculum (Jabbi et al., 2007), which are the brain area related to empathy (Singer et al., 2004; Decety & Jackson, 2004; Jackson et al., 2006). Furthermore, in fMRI study by Chakrabarti et al. (2006), participants observed short movie clips of happy, angry, sad and disgusted faces and their empathy trait was measured using the EQ (Baron-Cohen

& Wheelwright, 2004). The results showed that, across all facial expressions, empathy trait correlated positively with activation of the inferior frontal gyrus and ventral premotor cortex (Chakrabarti et al., 2006).

In ERP study by Soria Bauser et al. (2012), participants were instructed to discriminate the emotional facial expressions (happy, angry, or neutral) by pressing the button. The ERP result showed that the participants with higher IRI (Davis, 1983) and BEES (Mehrabian & Epstein, 1972), compared with those with low IRI and BEES, showed more negative N170 in response to angry faces. N170 is one of ERP components and increased negativity of N170 reflects increased attention to faces (for details, refer to 1.1.3 Event-related potential (ERP)). Thus, the result (Soria Bauser et al., 2012) indicates that individuals with high empathy trait pay attention from approximately 170 ms after watching angry face more than those with low empathy trait. Furthermore, the behavioral results showed that participants with higher IRI and BEES showed faster and more accurate response during discriminating facial expressions (Soria Bauser et al., 2012), suggesting that individuals with high empathy show superior performance in face processing than those with low empathy.

In EEG study by Choi & Watanuki (2012), participants watched images of people showing pleasant emotions (for example, depicting familial love) after watching discomfort-inducing images. The result showed that alpha power decreased during watching discomfort-inducing images and then increased during watching images of people showing pleasant emotions (Choi & Watanuki, 2012). More importantly, participants with higher IRI showed greater increase of alpha power during watching images of people showing pleasant emotions (Choi & Watanuki, 2012). Previous study has reported that there is negative correlation between alpha power and the subjective arousal level (Simons et al., 2003). Moreover, stress is related with high arousal, anxious, and fatigue (Tepas & Price, 2001). Thus, the study by Choi & Watanuki (2012) suggests that watching images showing pleasant emotions might reduce stress and this effect might be greater in individuals with high empathy trait than in those with low empathy trait. This might be because individuals with high empathy trait are sensitive to stimuli containing human figures, more than those with low empathy trait.

1.2.3 Event-related potential (ERP)

ERP has been used to study cognition, emotion, and attention in many researches. It reflects a specific neuro-cognitive process, as Bressler (2002) mentioned about ERP as follows:

"The event-related potential (ERP) is a neural signal that reflects coordinated neural network activity. The cortical ERP provides a window onto the dynamics of network activity in relation to a variety of different cognitive processes at both mesoscopic and macroscopic levels on a time scale comparable to that of single-neuron activity."

ERP is deeply related with electrophysiological correlates of attention (reviewed in Hermann & Knight, 2001; Schupp et al., 2006). For example, P300 (defined as LPP in this thesis), the most well-studied ERP component, reflects the voluntary object-selective direction of attention (Hermann & Knight, 2001). In addition, N1 is also modulated by attention, although it is elicited at a very early stage (e.g. before 200 ms) (Hermann & Knight, 2001).

Among many ERP components, the present thesis focused on N170 and LPP.

N170

N170 is called a face-selective component, as the negative peak is shown in the posterior temporal areas around 170 ms after face onset (Bentin et al., 1996; Campanella et al., 2000; Eimer & Holmes, 2002; Holmes et al., 2003; Taylor et al., 1999) (refer to Fig. 1.1). N170 is more negative when faces are attended than when faces are presented outside the attentional focus (Holmes et al., 2003). In addition, it has been reported that adults show more negative N170 amplitude and shorter N170 latency compared with children (Taylor et al., 1999), suggesting age-related development of face processing. Thus, more negative N170 appears to reflect increased attention to faces.

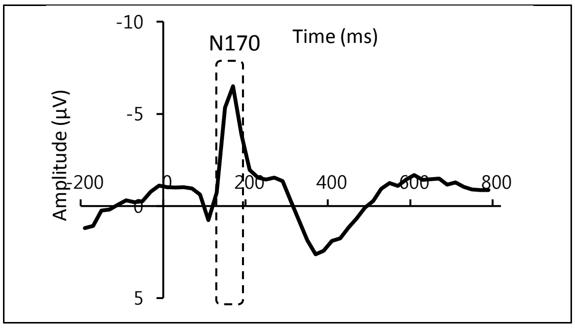

Fig. 1.1 Example of N170 component

Furthermore, N170 has been reported to be more negative at the right posterior temporal area than at the left posterior temporal area (Bentin et al., 1996; Campanella et al., 2000; Taylor et al., 1999). In this context, Campanella et al. (2000) argued that the perception of human faces is associated with the right posterior temporal area.

LPP

LPP is a positive slow wave beginning about 200 ms after stimulus onset and appearing maximal at centroparietal sites (Cuthbert et al., 2000; Schupp et al., 2000; Foti et al., 2009; Weinberg et al., 2012) (refer to Fig. 1.2). Many ERP studies have reported that LPP amplitude is greater in response to emotionally arousing (positive or negative) pictures than in response to emotionally neutral pictures (Cuthbert et al., 2000; Olofsson & Polich, 2007; Foti et al., 2009; Bradley et al., 2007; Keil et al., 2002). In addition, LPP amplitude correlates positively with the subjective arousal level (Cuthbert et al., 2000). LPP thus has been thought to reflect the motivational significance of emotional stimuli (Cuthbert et al., 2000; Lang et al., 1997; Olofsson & Polich, 2007; Schupp et al., 2000).

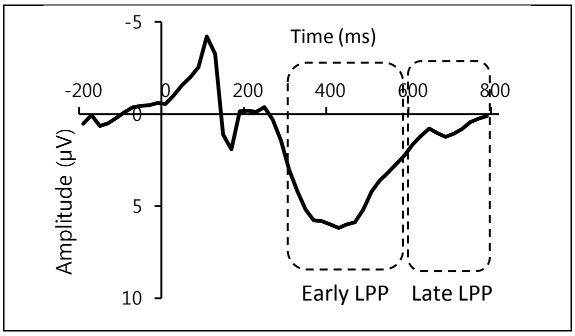

Fig. 1.2 Example of LPP component

In addition, the later LPP (>600 ms) seems to represent a different component to the earlier LPP (<600 ms, defined as P3 or P300 in some studies) (Foti et al., 2009; Kujawa et al., 2012) (refer to Fig. 1.2). Recent studies have suggested that earlier LPP reflects obligatory capture of attention, whereas later LPP reflects elaborate processing and sustained attention (Weinberg et al., 2012; Olofsson et al., 2008; Weinberg & Hajcak, 2011). This suggests the necessity of analyzing earlier LPP and later LPP separately.

1.2.4 Gender difference in attention to faces

Many psychological and physiological studies have revealed gender differences in the processing of human faces. For example, according to a review by McClure (2000), psychological results have indicated that females show superior performance in facial expression processing compared to males.

Numerous fMRI studies have revealed that there are gender differences in brain activities elicited during processing of human faces (e.g., Lee et al., 2002; Schulte-Rüther et al., 2008; Spreckelmeyer, 2009). For example, in fMRI study of Schulte-Rüther et al. (2008), participants rated their emotional states in response to emotional faces. The results (Schulte-Rüther et al., 2008) indicated that females, compared with males, showed stronger activation in right inferior frontal cortex and superior temporal sulcus, areas which have been reported to be related with experience sharing (Carr et al., 2003). On the other hand, males, compared with females, showed stronger activation in left temporo-parietal junction (Schulte-Rüther et al., 2008), an area which has been reported to be related with perspective taking (Vogeley et al., 2003).

ERP studies have also indicated gender differences in the processing of human faces (Campanella et al., 2004; Gullim & Mugrass, 2005; Orozco & Ehlers, 1998; Proverbio et al., 2009; Sun et al., 2010; Wang et al., 2011). In particular, several studies

(Gullim & Mugrass, 2005; Orozco & Ehlers, 1998; Proverbio et al., 2009) have revealed gender differences in LPP. For instance, an ERP study by Orozco & Ehlers (1998) found that females showed greater LPP (defined as P450 in that study) than males when discriminating faces with happy and sad expressions from emotionally neutral faces. Given that LPP reflects the motivational significance of stimuli and increased LPP relates to increased attention to stimuli (for details, refer 1.1.3 Event-related potential (ERP)), that result (Orozco & Ehlers, 1998) could be interpreted as showing that females are more sensitive and pay more attention to human faces compared with males.

Some authors (Proverbio et al., 2009; Han et al., 2008) have interpreted the greater LPP amplitude elicited in response to human figures (for example, human faces (Proverbio et al., 2009) and human hands (Han et al., 2008)) from females than from males as related to a higher empathic ability of females compared to males. Indeed, some psychological studies (Davis, 1983; Baron-Cohen & Wheelwright, 2004) have reported that females have a higher empathy trait than males, using questionnaires such as the IRI. However, previous studies investigating gender differences in LPP elicited by human faces (Gullim & Mugrass, 2005; Orozco & Ehlers, 1998; Proverbio et al., 2009) or human hands (Han et al., 2008) have not measured the empathy trait of participants using questionnaires such as the IRI. It thus remains unclear whether females show greater LPP in response to faces than males even when empathy trait does not differ between genders.

On the other hand, in many ERP studies that have investigated attention responses to faces, N170 has been measured as an index of early face processing. Previous psychological results (McClure, 2000) and LPP results (Campanella et al., 2004; Guillem & Mograss, 2005; Proverbio et al., 2009) on gender differences in face processing have led us to hypothesize that gender difference might exist in N170. However, previous studies (Sun et al., 2010; Wang et al., 2011; Batty & Taylor, 2003; Proverbio et al., 2006) have shown varying results on this issue. For example, no gender difference in N170 was elicited during discrimination of non-facial stimuli (i.e., cars or planes) from facial stimuli (Batty & Taylor, 2003), or during discrimination of familiar faces (faces of the subject or their parents) from unfamiliar faces (faces of strangers) (Wang et al., 2011). However, in a study by Sun et al. (2010), female participants showed more negative N170 when discriminating orientations (right or left) of faces than genders of faces, while male participants did not. From this result, the authors suggested that the effect of task demands on N170 is more obvious in females than in males (Sun et al., 2010). Whether males and females show different N170 responses during face processing thus has yet to be clarified.

1.3 The purpose of this thesis

In order to extend the knowledge of individual difference in attention response to faces, the present study aimed to investigate effect of empathy trait (as measured by the IRI) and gender on attention to faces.

Effect of empathy trait on attention to face and non-face stimuli (Chapter 2)

As mentioned in 1.2.2 Relationship between empathy trait and brain activity, many neuroscience studies have reported that there are clear relationship between empathy trait and attention to faces. However, it was still unclear whether there is relationship between empathy trait and LPP elicited by faces. Thus, in the first experiment, I aimed to examine the relationship between empathy trait (as measured by the IRI) and the LPP elicited by discriminating facial expressions (happy or angry). I predicted that individuals with high empathy, compared with those with low empathy, would show greater amplitude of the LPP in response to faces, reflecting enhanced attention to faces in individuals with higher empathy.

In addition, in the first experiment, I also examined the relationship between empathy trait and LPP elicited by discriminating flower colors (yellow or purple), which was presented as stimuli not containing human figures. ‘Human’ elements such as human faces and voices provide important cues for triggering empathy. I can thus predict that, when discriminating characteristics of non-face stimuli (for example, flower colors), individuals with high empathy and those with low empathy should not attend to the stimulus differently. I thus predicted that no difference would exist between individuals with high empathy and those with low empathy in the LPP response elicited by discriminating flower colors.

Gender difference in attention to face and non-face stimuli (Chapter 3)

As mentioned in 1.2.4 Gender difference in attention to faces, many psychological and physiological studies have reported that males and females show different attention response to faces. However, it is still unclear whether there is gender difference in LPP elicited by faces, even when empathy trait does not differ between genders. In the first experiment, male and female participants did not show difference in empathy trait (see 3.3.1 Empathy trait). Thus, I reanalyzed data from the first experiment and investigated gender difference in LPP elicited by discriminating facial expressions (happy or angry) and flower colors (yellow or purple). I predicted that females, compared with males, would show more positive LPP when discriminating facial expressions, if gender differences in face processing exist even when empathy trait does not differ between genders.

Effect of empathy trait on attention to various facial expressions (Chapter 4)

In the second experiment, I aimed to investigate the relationships between the empathy trait and attention to five facial expressions (happy, angry, surprised, afraid, and sad), as only two facial expressions (happy and angry) were presented as stimuli in the first experiment.

Since Ekman and Friesen (1971) investigated the universality of facial expressions of emotion, basic facial expressions have generally been thought to comprise the following six expressions: happiness; anger; surprise; fear; sadness; and disgust. However, very few studies have investigated the relationship between empathy trait and attention to those various facial expressions. As mentioned in 1.2.2 Relationship between empathy trait and brain activity, empathy trait in previous studies was correlated with the brain activity elicited by discriminating happy, angry, and neutral faces (Soria Bauser et al., 2012), observing pleased, disgusted and neutral facial expressions (Jabbi et al., 2007).

To the best of my knowledge, only one study (Chakrabarti et al., 2006) examined the relationship between empathy trait and attention to more than four expressions, using neurotypical adult participants as subjects. In an fMRI study by Chakrabarti et al. (2006), the empathy trait of participants was measured using the EQ (Baron-Cohen & Wheelwright, 2004), with participants observing short movie clips of happy, angry, sad and disgusted faces. The results showed that, across all facial expressions, empathy trait correlated positively with brain activity (for details, see 1.2.2 Relationship between empathy trait and brain activity). However, differences were also seen in brain areas which correlated with empathy trait depending on the facial expressions viewed (for example, for happy faces, EQ correlated with ventral striatal response; for angry faces, EQ correlated with precuneal and lateral prefrontal cortical response), suggesting different evolutionary functions of each emotion (Chakrabarti et al., 2006).

However, it is necessary to use ERP to clarify how early empathy trait starts to affect the attention processing of various facial expressions, since ERP provides high temporal resolution (refer to 1.2.3 Event-related potential (ERP)). The high temporal resolution of ERP is thought to enable us to clarify whether empathy trait is related to the very early stage (reflected in N170) and late stage (reflected in LPP) of attention to facial expressions.

Moreover, which aspect of empathy is correlated with those facial expressions is still unclear, because the EQ questionnaire (Baron-Cohen & Wheelwright, 2004) used by Chakrabarti et al. (2006) lacks the subscales reflecting various aspects of empathy included in the IRI (For details, refer to 1.2.1 Empathy). Examination of relationships between empathy and attention response to faces using the IRI is thus warranted.

Thus, in the second experiment, I investigated the relationship between IRI and ERP responses (N170 and LPP) elicited by discriminating various facial expressions (happy, angry, surprised, afraid, and sad) from emotionally neutral faces. I predicted that individuals with high empathy trait would pay more attention to those facial expressions (happy, angry, surprised, afraid, and sad) and may thus show a more negative N170 and a more positive LPP compared to individuals with low empathy.

Gender difference in attention to various facial expressions (Chapter 5)

In the second experiment, male and female participants did not show difference in empathy trait (see 5.3.1 Empathy trait), such as in the first experiment. Thus, I reanalyzed data from the second experiment and investigated gender difference in LPP elicited by discriminating facial expressions (happy, angry, surprised, afraid, and sad) from emotionally neutral faces, in order to examine whether there is gender difference in attention to those facial expressions exist even when empathy trait does not differ between genders.

In addition, as mentioned in 1.2.4 Gender difference in attention to faces, previous studies have shown varying results on gender difference in N170. Thus, I aimed to investigate whether there is gender difference in N170 elicited by discriminating emotional facial expressions from emotionally neutral faces, by reanalyzing the data from the second experiment.

1.4 The structure of this thesis

This thesis is divided into two parts: effect of empathy trait on attention to faces, and gender difference in attention to faces.

Effect of empathy trait on attention to faces was described in Chapter 2 and Chapter 4. In Chapter 2, relationships between empathy trait and attention to face and non-face stimuli were analyzed based on data from the first experiment. In Chapter 4, relationships between empathy trait and attention to various facial expressions were analyzed based on data from the second experiment.

Gender difference in attention to faces was described in Chapter 3 and Chapter 5. In Chapter 3, gender differences in attention to face and non-face stimuli were analyzed based on data from the first experiment. In Chapter 5, gender differences in attention to various facial expressions were analyzed based on data from the second experiment.

Finally, I summarized my conclusions in Chapter 6.

Chapter 2
Effect of empathy trait on attention to face and non-face stimuli

2.1 Introduction

Empathy is defined as 'the ability to imagine oneself in another's place and understand the other's feelings, desires, ideas, and actions (Encyclopedia Britannica, 1999 edition)'. Humans are considered social animals (Gazzaniga, 2008) and empathy is thus an essential ability required for social activities of human being. However, individual differences exist in the empathy trait, suggesting that ability and methods to adapt to social environments differ depending on the individual.

In previous psychological studies, individual differences in empathy have been measured using questionnaires (Davis, 1983; Mehrabian & Epstein, 1972; Baron-Cohen & Wheelwright, 2004). For example, Davis (1983) developed the Interpersonal Reactivity Index (IRI), which is a questionnaire measuring empathy trait of individuals by using four subscales: perspective taking; fantasy; empathic concern; and personal distress. Perspective taking subscale measures attempts to take the perspectives of others, while fantasy subscale measures tendency to identify with fictitious characters (Davis, 1983). Empathic concern subscale measures tendency to feel warmth and compassion for others, while personal distress subscale measures discomfort elicited by observing the negative experiences of others (Davis, 1983).

Individual differences in empathy trait have been investigated not only in psychological studies, but also in neuroscience studies (Jabbi et al., 2007; Singer et al., 2004; Hooker et al., 2008; Krämer et al., 2010; Chakrabarti et al., 2006; Soria Bauser et al., 2012). For example, functional magnetic resonance imaging (fMRI) study by Jabbi et al (2007) showed that participants with higher IRI, compared with those with low IRI, showed greater activation of the anterior insula and frontal operculum during observing the facial expressions. This result suggests a possibility that individuals with high empathy trait might pay attention to faces of others more than those with low empathy trait.

However, it was still unclear whether there is relationship between empathy trait and late positive potential (LPP) component of event-related potential (ERP) elicited by faces. LPP is a positive slow wave beginning about 200 ms after stimulus onset and is thought to reflect the motivational significance of emotional stimuli (Cuthbert et al., 2000; Lang et al., 1997; Olofsson & Polich, 2007; Schupp et al., 2000). Thus, if individuals with high empathy pay attention to faces more than those with low empathy trait, individuals with higher empathy would show greater amplitude of the LPP in response to faces.

In addition, 'Human' elements such as human faces and voices provide important cues for triggering empathy. I can thus predict that, when presented with non-face stimuli (for example, flowers), individuals with high empathy and those with low empathy should not attend to the stimulus differently.

In this chapter, I thus aimed to examine the relationship between empathy trait (as measured by the IRI) and the LPP elicited by discriminating facial expressions (happy or angry). Participants discriminated images of facial expressions (happy or angry) and flower colors (yellow or purple) presented in oddball paradigm. I predicted that individuals with higher empathy would show greater amplitude of the LPP during discriminating facial expressions, but during discriminating flower colors, reflecting enhanced attention only to stimuli containing human figures among individuals with higher empathy.

2.2 Methods

Participants

Thity-two Japanese university or graduate school students participated in the study (17 men, 15 women; age range, 19 to 28 years; all right-handed). Participants had normal or corrected-to-normal color vision and were not using prescription medications. They filled out the Japanese version (Sakurai, 1998) of the IRI (Davis, 1983) using responses on a scale of 1 ('does not describe me well') to 4 ('describes me very well'). Written informed consent was obtained from all participants prior to participation. All study protocols were approved by the ethics committee in the Department of Design at Kyushu University, Japan.

As progesterone levels have been reported to increase LPP amplitude during the period from 4-10 days before menstruation (Johnson & Wang, 1991), female participants participated in the experiment during a time that excluded this period.

Stimuli and procedure

For images of human faces, images of 12 adult humans (6 men, 6 women) showing two types of facial expression (happy and angry) were taken from the Karolinska Directed Emotional Faces (Lundqvist et al., 2011) for a total of 24 images. Images of flowers were taken from the Internet. Twelve different images of flowers in two colors (yellow and purple) were selected (24 images in total). All images were edited to 300 × 400 pixels and presented in the centre of a black screen (17-inch monitor, 1,024 × 768 resolution).

The experiment comprised four blocks of oddball tasks. In Block 1, the target was a happy face image, and the non-target was an angry face image (Table 2.1). In Block 2, the target was a yellow flower image, and the non-target was a purple flower image (Table 2.1). In Blocks 3 and 4, targets and non-targets of Blocks 1 and 2 were reversed (Table 2.1). Participants were instructed to press a key with the right hand as soon as they saw the target. They therefore discriminated facial expressions (happy or angry) in Blocks 1 and 3, and flower colors (yellow or purple) in Blocks 2 and 4. Each block consisted of 60 trials, during which the target was presented 20% of the time (12 trials). In each block, each target image was shown once, and each non-target image was shown four times.

Table 2.1 Target and non-target stimuli

Block	Target (20%)	Non-target (80%)
1	Happy faces	Angry faces
2	Yellow flowers	Purple flowers
3	Angry faces	Happy faces
4	Purple flowers	Yellow flowers

Trials began with a 500-ms presentation of a cross shape followed by a random 800-ms presentation of a target or non-target image (Fig. 2.1). Targets were never presented on two consecutive trials. Trials were separated by a 1,000-ms interval (Fig. 2.1). This experimental design was based on that described by Fishman et al. (2011).

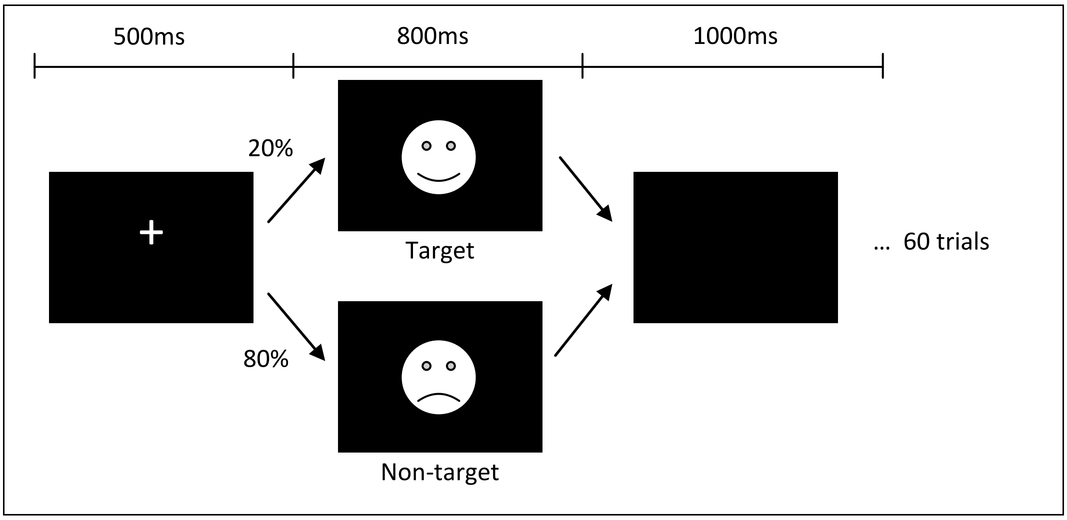

Fig. 2.1 Experimental procedure (block 1). After cross mark (500 ms), target of non-target was presented (800 ms). Target (happy face) was presented in 20% probability and non-target (angry face) was presented in 80% probability. The faces in this figure were drawn only for illustrative purposes, because Karolinska Directed Emotional Faces (Lundqvist et al., 2011) are not intended for publication.

After oddball tasks were completed, participants filled out subjective assessments. They once again observed the images presented in the oddball tasks, and judged the valence and arousal of each image based on a 7-point Likert scale (for valence, ‘very pleasant’ was given 3 points and ‘very unpleasant’ -3 points; for arousal, ‘very aroused’ was given 3 points and ‘very relaxed’ -3 points).

ERP measurements and analysis

Electroencephalography (EEG) was recorded using a Polymate AP1532 system (TEAC co., Tokyo, Japan). As seen in Fig. 2.2, measurement sites were Cz (medial central), Pz (medial parietal), and Oz (medial occipital) sites based on the International 10–20 system (Towle et al., 1993), with averaged ears as reference. In the analysis, I focused on Cz and Pz sites because the LPP has shown to be maximal at the centroparietal site (for example, Cuthbert et al., 2000; Schupp et al., 2000; Foti et al., 2009; Weinberg & Hajcak, 2011). Electrooculography (EOG) was recorded to detect blinking with electrodes above and below the right eye. All electrode impedances were below 10 kΩ.

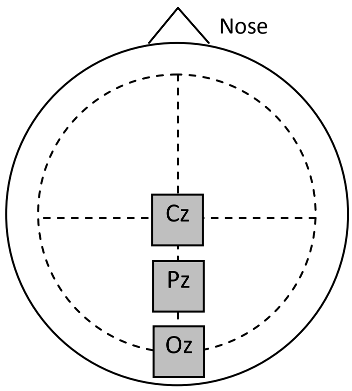

Fig. 2.2 Location of electrodes

The EMSE Suite (Source Signal Imaging, San Diego, CA, USA) was used for ERP analysis. EEG signals were recorded at a sampling rate of 250 Hz and filtered with a low-frequency cutoff of 0.1 Hz and a high-frequency cutoff of 40 Hz. Blinking was corrected with the EMSE Ocular Artifact Correction Tool (for details, see Ally et al., 2009). Trials containing artifacts of 50 μV and trials during which the subject did not press a key were excluded from averages. Target stimulus presentation of -200 to 800 ms was averaged (baseline: stimulus presentation of -200 to 0 ms) for blocks with faces (Blocks 1 and 3) and flowers (Blocks 2 and 4). The mean number of trials was 22.7 (standard deviation (SD) = 1.5) for faces, 22.8 (SD = 2.3) for flowers.

Early LPP was quantified as mean amplitude in the 300 to 600 ms after stimulus onset and late LPP was quantified as mean amplitude in the 600 to 800 ms after stimulus onset (see Fig. 2.3).

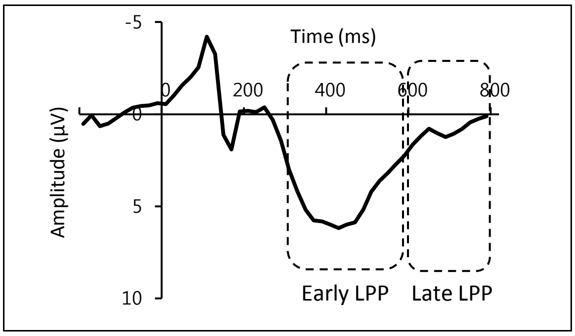

Fig. 2.3 Calculation of ERP response

Statistical analysis

ERP responses and behavioral responses (response accuracies, reaction times, and subjective ratings) and were subjected to paired t-testing for comparisons between the two stimulus types (faces vs. flowers). To investigate relationships between empathy trait and responses to stimuli, I correlated IRI score with ERP responses and behavioral data (Pearson's correlation coefficient).

SPSS software (SPSS, Chicago, IL, USA) was used for statistical analysis. Statistical significance was at a level of 5% ($p < 0.05$). I analyzed male and female data together, since no significant gender differences were apparent in IRI score (for details, see Chapter 3).

2.3 Results

2.3.1 Empathy trait

Table 2.2 shows IRI scores of participants.

Table 2.2 IRI scores

	Range	Mean (SD)
Total score	60 to 95	79.0 (10.2)
Perspective taking	14 to 26	20.4 (3.3)
Fantasy	12 to 27	20.9 (4.1)
Empathic concern	14 to 26	20.5 (2.9)
Personal distress	11 to 22	17.2 (2.8)

Note. n = 32

SD: Standard deviation

2.3.2 ERP responses

Fig. 2.4 shows grand-averaged ERP waveforms.

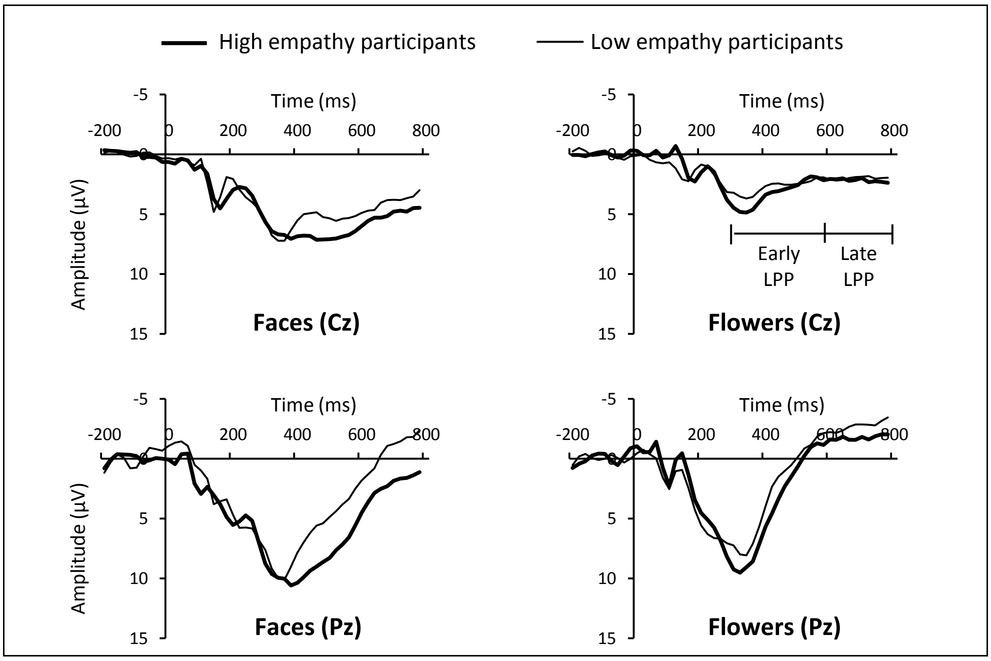

Fig. 2.4 Grand-averaged ERP waveforms. High empathy participants (thick line, n = 18, range of total IRI scores: 82 to 95) and low empathy participants (thin line, n = 14, range of total IRI scores: 60 to 75) were labelled only for illustrative purposes. Left column indicates response to faces and right column indicates response to flowers.

Early LPP

The early LPP was significantly greater in response to faces than in response to flowers (Cz: t = 6.58, Pz: t = 8.89, all $df = 31$, $p < 0.001$). Mean amplitude of early LPP elicited at Cz was 6.3 µV (SD = 3.3) and 3.0 µV (SD = 2.0) for faces and flowers, respectively. Mean amplitude of early LPP elicited at Pz was 7.8 µV (SD = 3.4) and 3.3 µV (SD = 2.3) for faces and flowers, respectively.

Correlations between IRI scores and early LPP are shown in Table 2.3. Total IRI score showed a significant positive correlation with early LPP elicited by faces at the Pz site ($r = 0.38$, $p < 0.05$) (Table 2.3, Fig. 2.5). For flowers, early LPP did not show any significant correlation with IRI (all $p > 0.05$) (Table 2.3).

Table 2.3 Correlations between IRI score and early LPP

Early LPP \ IRI	Total score	Perspective taking	Fantasy	Empathic concern	Personal distress
Faces					
Cz	0.29	0.09	0.30	0.28	0.20
Pz	0.38*	0.27	0.33	0.27	0.31
Flowers					
Cz	0.11	-0.01	0.14	0.05	0.15
Pz	0.19	0.21	0.16	0.06	0.15

Note. $n = 32$
*p < 0.05, Pearson correlation

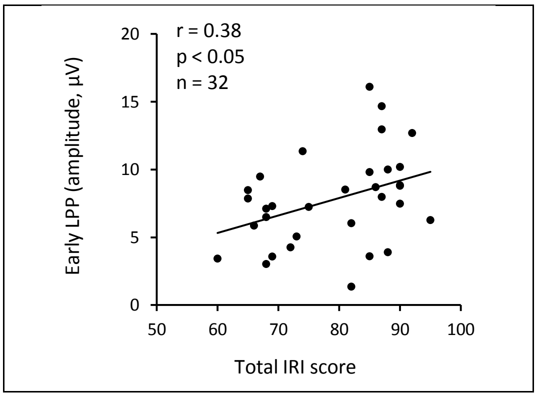

Fig. 2.5 Correlation between IRI score and early LPP (Pz). Total IRI score correlated with early LPP elicited by faces positively and significantly (Pearson's correlation, $r = 0.38$, $p < 0.05$).

Late LPP

Late LPP was also significantly greater in response to faces than in response to flowers (Cz: t = 4.74, Pz: t = 6.73, all $df = 31$, $p < 0.005$). Mean amplitude of late LPP elicited at Cz was 4.6 µV (SD = 3.2) and 2.1 µV (SD = 2.7) for faces and flowers, respectively. Mean amplitude of late LPP elicited at Pz was 1.1 µV (SD = 3.5) and -2.2 µV (SD = 3.4) for faces and flowers, respectively.

Correlations between IRI scores and late LPP are shown in Table 2.4. Total IRI score showed a significant positive correlation with late LPP elicited by faces at the Pz site ($r = 0.42$, $p < 0.05$) (Table 2.4, Fig. 2.6). Furthermore, as shown in Table 2.4, the fantasy subscale of IRI correlated significantly and positively with late LPP elicited by faces (Cz: $r = 0.41$, $p < 0.05$; Pz: $r = 0.47$, $p < 0.01$). In addition, the personal distress subscale of IRI also showed a significant positive correlation with late LPP elicited by faces at the Pz site ($r = 0.38$, $p < 0.05$) (Table 2.4). For flower stimuli, late LPP did not show any significant correlation with IRI (all $p > 0.05$) (Table 2.4).

Table 2.4 Correlations between IRI score and late LPP

Late LPP \ IRI	Total score	Perspective taking	Fantasy	Empathic concern	Personal distress
Faces					
Cz	0.30	0.00	0.41*	0.31	0.17
Pz	0.42*	0.21	0.47**	0.19	0.38*
Flowers					
Cz	0.07	-0.20	0.24	0.02	0.12
Pz	0.13	-0.06	0.24	-0.01	0.19

Note. *n* = 32
*p < 0.05, **p < 0.01, Pearson correlation

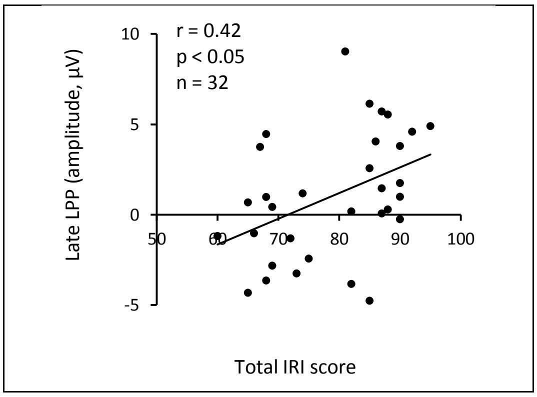

Fig. 2.6 Correlation between IRI score and late LPP (Pz). Total IRI score correlated with early LPP elicited by faces positively and significantly (Pearson's correlation, $r = 0.42$, $p < 0.05$).

2.3.3 Behavioral responses

Response accuracies and reaction time

Table 2.5 shows response accuracies and reaction time. Response accuracies were significantly ($t = -3.96$, $df = 31$, $p < 0.001$) higher in response to flowers than in response to faces (Table 2.5). Reaction times were significantly ($t = 12.80$, $df = 31$, $p < 0.001$) longer in response to faces than in response to flowers (Table 2.5). IRI results did not correlate significantly with response accuracies or reaction times (all $p > 0.05$).

Table 2.5 Response accuracies and reaction time

	Response accuracies (%)	Reaction time (ms)
Faces	98.6 (1.5)	424.2 (70.7)
Flowers	99.7 (0.7)	327.3(38.5)

Note. *n* = 32
Mean (Standard deviation)

Subjective ratings

Table 2.6 shows subjective ratings. Valence rating indicated that flowers were rated as significantly (t = -6.03, *df* = 31, $p < 0.001$) more pleasant than faces. Arousal rating showed that faces were significantly (t = -7.05, *df* = 31, $p < 0.001$) more arousing stimuli compared with flowers. IRI did not correlate significantly with subjective ratings (all $p > 0.05$).

Table 2.6 Subjective ratings

	Valance	Arousal
Faces	-0.2 (0.4)	1.3 (0.9)
Flowers	0.9 (0.9)	-0.1 (0.9)

Note. *n* = 32

Mean (Standard deviation)

Valance: 'very pleasant', 3; 'very unpleasant' -3

Arousal: 'very aroused' 3; 'very relaxed' -3

2.4 Discussion

In this chapter, I investigated whether individuals with high empathy pay attention when discriminating facial expressions differently from those with low empathy. I examined the relationship between empathy trait (IRI) and LPP.

Empathy trait and response to discrimination of facial expressions

Consistent with my hypothesis, there were positive correlations between IRI scores and LPP elicited by faces (Table 2.3). As mentioned in 1.2.3 Event-related potential (ERP), LPP reflects the motivational significance of stimuli (Weinberg et al., 2013; Lang et al., 1997; Schupp et al., 2000). Thus, the present finding indicates that individuals with high empathy pay attention to human faces more than individuals with low empathy when discriminating facial expressions. This strongly supports the previous studies that argued brain activity from stimuli containing human figures differs between people shown by the IRI to have high levels of empathy and those shown to have low levels (Choi & Watanuki, 2012; Hooker et al., 2008; Jabbi et al., 2007; Krämer et al., 2004; Singer et al., 2004). I argue that this is because individuals with high empathy tend to try to correctly gauge the emotional state and intentions of other people more than individuals with low empathy. There thus seem to be distinct differences in the methods of adapting to social environments between individuals with high and low empathy.

I analyzed early LPP (300 to 600 ms) and late LPP (600 to 800 ms) separately and found that both correlated positively with total IRI score (Table 2.3; Table 2.4; Fig. 2.5; Fig. 2.6). According to previous studies, the later LPP (>600 ms) seems to represent a different component to the earlier LPP (<600 ms, defined as P3 or P300 in some studies) (Foti et al., 2009; Kujawa et al., 2012). Recent studies have suggested that earlier LPP reflects obligatory capture of attention, whereas later LPP reflects elaborate processing and sustained attention (Weinberg & Hajcak, 2011; Weinberg et al., 2012; Olofsson et al., 2008). Thus, the present result indicates that empathy is associated not only with obligatory capture of attention by faces, but also with elaborate and sustained processing of faces. The present findings thus suggest empathy trait as one of the factors eliciting individual differences in the processing of faces.

I found that late LPP elicited by faces correlated positively with fantasy and personal distress scales, but not with perspective taking or empathic concern scales (Table 2.4). This is consistent with the findings of Jabbi et al. (2007), who demonstrated that the fantasy and personal distress scales showed stronger correlations with activation of the anterior insula and frontal operculum elicited by observing facial expressions than other subscales of the IRI. Personal distress has been suggested to be associated with self-oriented empathic response (that is, imagining oneself to be in the situation of others), while empathic concern is associated with other-oriented empathic response (that is, imagining the feelings of others) (Lamm et al., 2007). In addition, the fantasy scale seems to reflect self-oriented empathic response more than other-oriented empathic response, given that it measures the tendency to identify with characters in fictional situations (Davis, 1983). The present study suggests that responses to faces are associated with self-oriented empathic response, as reflected in the personal distress and fantasy scales of the IRI.

Empathy trait and response to discrimination of flower colors

In the present study, images of flowers were presented as non-face stimuli. As hypothesized, in response to discrimination of flower colors, IRI scores did not correlate with LPP (Table 2.3; Table 2.4). This indicates that no difference exists in attention when discriminating flower colors between individuals with high and low empathy. This may mean that, compared to individuals with low empathy, those with high empathy have a higher tendency to pay particular attention to human elements among the various stimuli they encounter. This might be because empathy is facilitated in response to stimuli that contain human figures (for example, human faces) more than in response to stimuli that do not contain human figures.

However, there is a limitation in this interpretation, since there were many differences between response to discrimination of facial expressions and discrimination of flower colors. First, both early LPP and late LPP were smaller in response to discrimination of flower colors compared with in response to discrimination of facial expressions. This reflects that degree of attention elicited when discriminating flower colors was not the same as that when discriminating facial expressions. Second, subjective ratings also revealed that images of faces were more arousing stimuli than images of flowers. Third, results of response accuracies and reaction times indicate that discriminating facial expressions was more difficult than discriminating flower colors.

Thus, in the future studies, stimuli with the same degree of arousal as human faces need to be used as non-face stimuli.

Limitations

There are some limitations in the present chapter. First, as mentioned above, LPP responses and behavioral responses indicated there were many differences between response to discrimination of facial expressions and discrimination of flower colors. Second, images of Caucasian faces (from Lundqvist et al, 2011) were presented as stimuli, although participants were all Japanese. This might have affected the results, because the participants might have been unacquainted with faces of different races. Third, I could not analyze ERP response to happy and angry faces separately, due to the limited average number of trials. Thus, the present finding could not identify relationship between empathy trait and LPP elicited by only happy faces (or angry faces). To answer this issue, I conducted revised oddball paradigm which let participants discriminate happy faces or angry faces from emotionally neutral faces in separated blocks (refer to Chapter 4).

Conclusions

The present study revealed that empathy trait (as determined using the IRI) correlated positively with both early (300 to 600 ms) and late (600 to 800 ms) portions of LPP elicited when discriminating facial expressions, but not flower colors. This indicates that individuals with high empathy trait, compared with those with low empathy trait, pay more attention to when discriminating facial expression, not when discriminating flower colors. This suggests a possibility that individuals with high empathy trait might have a tendency to be especially sensitive to face, not to non-face stimuli (for example, flowers).

Chapter 3
Gender difference in attention to face and non-face stimuli

3.1 Introduction

Many neuroscience studies have revealed gender differences in the processing of human faces (Lee et al., 2002; Schulte-Rüther et al., 2008; Spreckelmeyer, 2009; Campanella et al., 2004; Gullim & Mugrass, 2005; Orozco & Ehlers, 1998; Proverbio et al., 2009; Sun et al., 2010; Wang et al., 2011). For example, an event-related potential (ERP) study by Orozco & Ehlers (1998) found that females showed greater late positive potential (LPP) (defined as P450 in that study) than males when discriminating faces with happy and sad expressions from emotionally neutral faces. Given that LPP reflects the motivational significance of stimuli and increased LPP relates to increased attention to stimuli (Cuthbert et al., 2000; Lang et al., 1997; Olofsson & Polich, 2007; Schupp et al., 2000), that result (Orozco & Ehlers, 1998) could be interpreted as showing that females are more sensitive and pay more attention to human faces compared with males.

However, it is still unclear whether there is gender difference in LPP elicited by faces, even when empathy trait does not differ between genders. This is because previous studies investigating gender differences in LPP elicited by human figures (Gullim & Mugrass, 2005; Orozco & Ehlers, 1998; Proverbio et al., 2009; Han et al., 2008) have not measured the empathy trait of participants using questionnaires such as the Interpersonal Reactivity Index (IRI). It thus remains unclear whether females show greater LPP in response to faces than males even when empathy trait does not differ between genders.

In this chapter, I thus aimed investigated gender differences in LPP elicited by discriminating facial expressions (happy or angry) and flower colors (yellow or purple), by reanalyzing data from my previous research (Chapter 2). As noted in Chapter 2, male and female participants did not show difference in IRI score, including scores of all subscales (perspective taking; fantasy; empathic concern; and personal distress). I predicted that females, compared with males, would show more positive LPP when discriminating facial expressions, if gender differences in face processing exist even when empathy trait does not differ between genders.

3.2 Methods

Participants and the experimental procedure were the same as in Chapter 2, except for statistical analysis.

In addition, I calculated LPP peak (most positive potential within 300-800 ms) (Fig. 3.1), in order to investigate gender difference in ERP responses in detail.

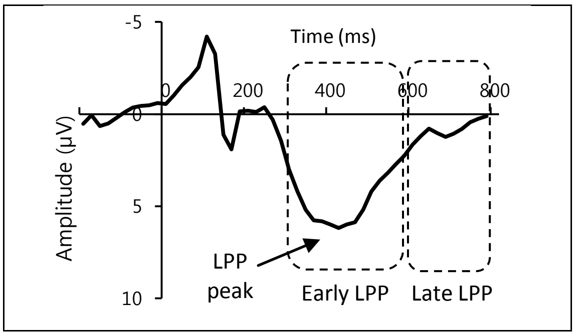

Fig. 3.1 Calculation of ERP response

Statistical analysis

IRI scores were subjected to independent t-test between genders. ERP responses and behavioral response (response accuracies, reaction times, and subjective ratings) were subjected to two-way analysis of variance (ANOVA) with Gender as a between-subjects factor and Stimuli (face vs. flower) as a within-subject factor.

SPSS software (SPSS, Chicago, IL, USA) was used for statistical analysis. Statistical significance was at a level of 5% ($p < 0.05$). The Greenhouse-Geisser correction was applied where sphericity was violated. When the main effect or an interaction was significant, pairwise comparisons were performed with the Bonferroni correction.

3.3 Results

3.3.1 Empathy trait

Table 3.1 shows empathy trait of male and female participants. There was no significant gender difference in IRI scores ($p > 0.05$, Table 3.1).

Table 3.1 IRI scores

	Mean (SD)		Gender difference[a]	
	Males	Females	t value	p value
Total score	77.5 (11.0)	80.8 (9.1)	-0.92	0.36
Perspective taking	20.1 (3.5)	20.9 (3.0)	-0.69	0.49
Fantasy	20.5 (4.4)	21.5 (3.8)	-0.69	0.50
Empathic concern	19.9 (2.9)	21.2 (2.8)	-1.31	0.20
Personal distress	17.1 (3.2)	17.3 (2.5)	-0.20	0.84

Note. *n* = 32 (male: 17; Female: 15)

SD: Standard deviation

[a]Independent t-test (*df* = 30)

3.2 ERP responses

Fig. 3.2 shows grand-averaged ERP waveforms.

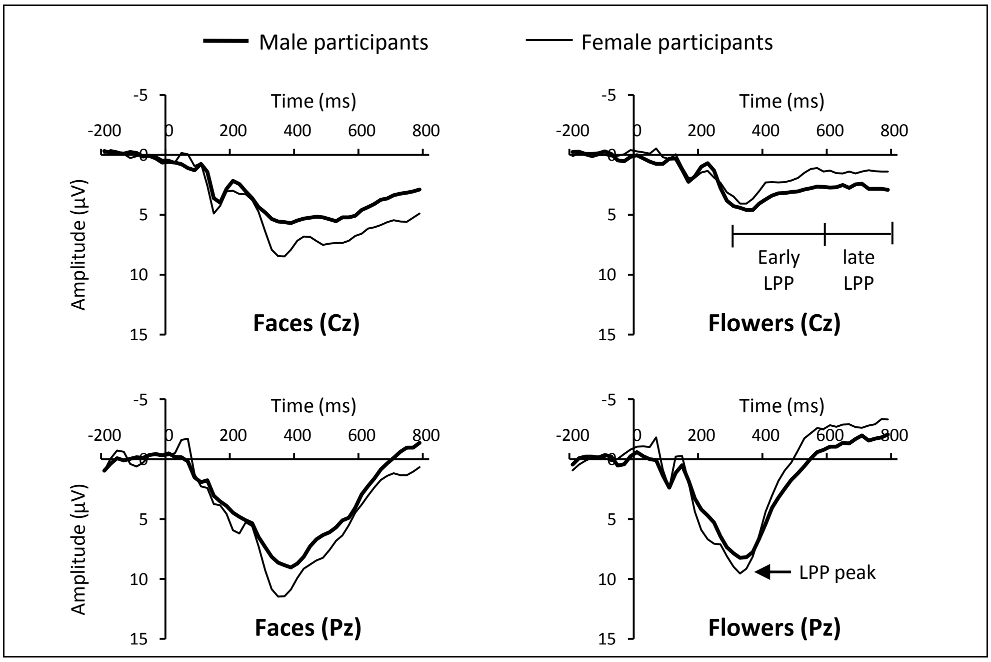

Fig. 3.2 Grand-averaged ERP waveforms. Male participants (n = 17) are shown in thick line and female participants (n = 15) are shown in thin line. Left column indicates response to faces and right column indicates response to flowers.

Early LPP

For early LPP, showed a significant main effect of Stimuli at Cz (F(1,30) = 64.6, $p < 0.001$) and Pz (F(1,30) = 98.2, $p < 0.001$), indicating that early LPP was greater in response to faces than flowers (Fig. 3.3). For early LPP, a reliable interaction of Stimuli × Gender was identified at Cz (F (1, 30) = 13.8, $p < 0.01$) and Pz (F (1, 30) = 7.3, $p < 0.05$), but no main effect of Gender (Fig. 3.3).

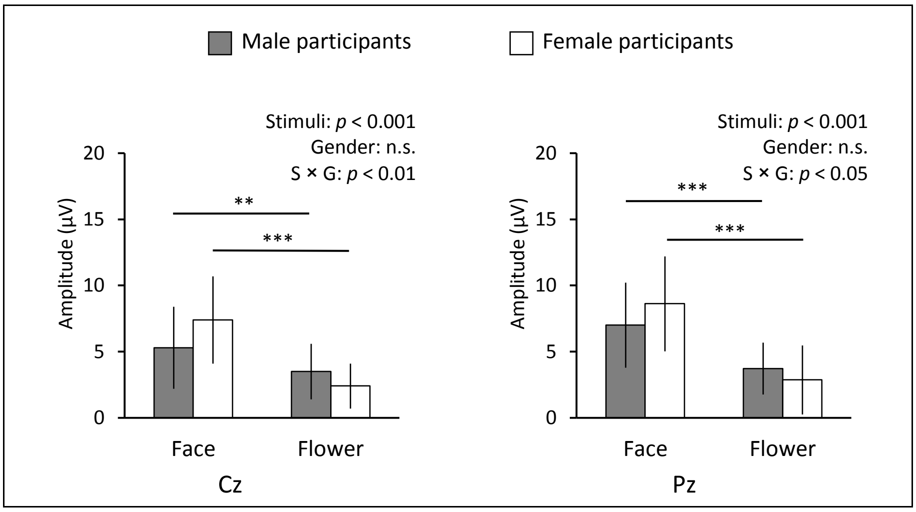

Fig. 3.3 Early LPP. Grey bar and white bar indicates male (n = 17) and female (n = 15) participants, respectively. **p < 0.01, ***p < 0.001 (Follow-up pairwise comparisons).

Separate analysis for comparisons between stimuli (face vs. flower) among each gender indicated that both males and females showed significantly greater early LPP in response to faces than flowers at Cz (male: $p < 0.01$; female; $p < 0.001$) and Pz (male: $p < 0.001$, female: $p < 0.001$) (Fig. 3.3).

Separate analysis for comparisons between males and females in each stimuli type showed that there was no significant difference between males and females in early LPP at Cz or Pz (all $p > 0.05$) (Fig. 3.3).

LPP peak

For LPP peak (Fig. 3.4), showed a significant main effect of Stimuli at Cz ($F(1,30) = 36.8$, $p < 0.001$) and Pz ($F(1,30) = 8.3$, $p < 0.01$), indicating that LPP peak was greater in response to faces than flowers. For LPP peak, a reliable interaction of Stimuli × Gender was identified at Cz ($F(1, 30) = 9.0$, $p < 0.01$), but no main effect of Gender (Fig. 3.4).

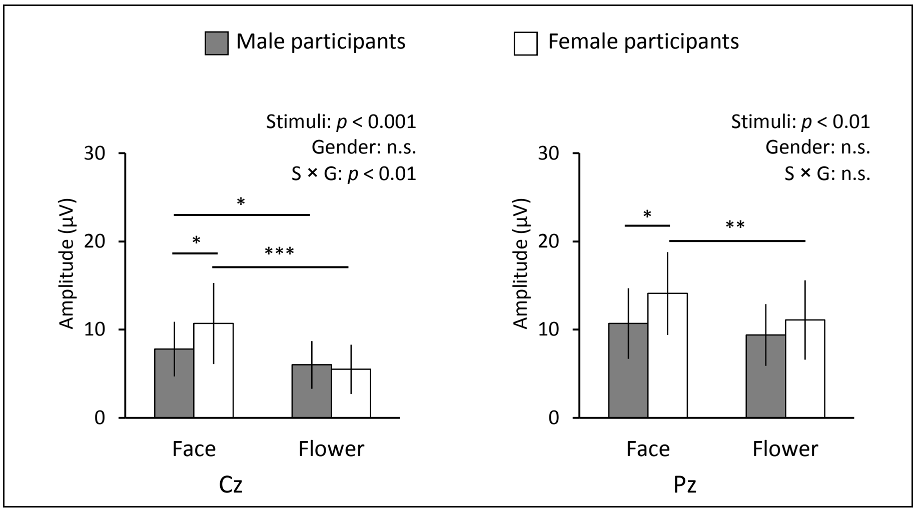

Fig. 3.4 LPP peak. Grey bar and white bar indicates male (*n* = 17) and female (*n* = 15) participants, respectively. *p < 0.05, **p < 0.01, ***p < 0.001 (Follow-up pairwise comparisons).

Separate analysis for comparisons between stimuli (face vs. flower) among each gender indicated that both males and females showed significantly greater LPP peak in response to faces than flowers at Cz (male: $p < 0.05$; female: $p < 0.001$) (Fig. 3.4). However, at Pz site, females showed significantly greater LPP peak in response to faces than in response to flowers ($p < 0.01$), but males did not (Fig. 3.4).

Separate analysis for comparisons between males and females in each stimuli type showed that LPP peak was significantly greater in females than in males in response to faces at Cz and Pz (all $p < 0.05$), but not in response to flowers (Fig. 3.4).

Late LPP

For late LPP (Fig. 3.5), showed a significant main effect of Stimuli at Cz ($F(1,30) = 35.0$, $p < 0.001$) and Pz ($F(1,30) = 62.3$, $p < 0.001$), indicating that late LPP was greater in response to faces than flowers. For late LPP, a reliable interaction of Stimuli × Gender was identified at Cz ($F(1, 30) = 14.8$, $p < 0.01$) and Pz ($F(1, 30) = 10.6$, $p < 0.01$), but no main effect of Gender (Fig. 3.5).

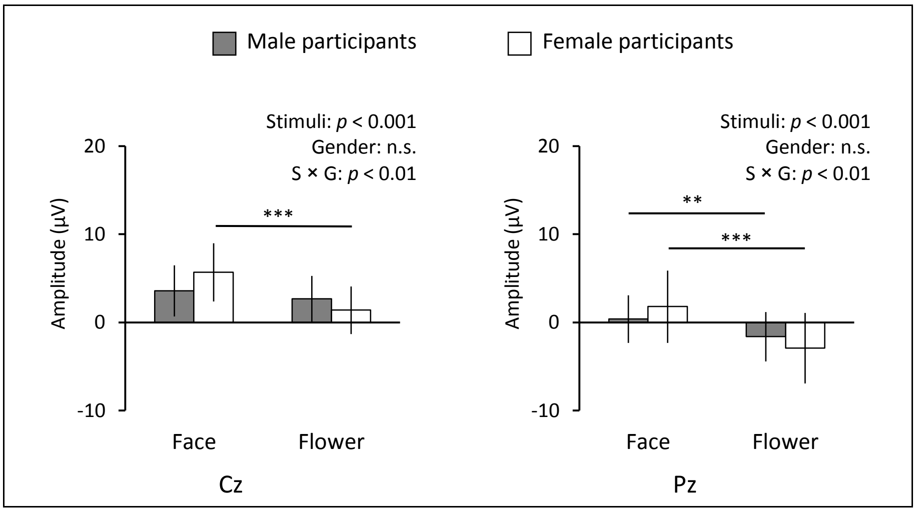

Fig. 3.5 Late LPP. Grey bar and white bar indicates male (*n* = 17) and female (*n* = 15) participants, respectively. **p < 0.01, ***p < 0.001 (Follow-up pairwise comparisons).

Separate analysis for comparisons between stimuli (face vs. flower) among each gender indicated that both males and females showed significantly greater late LPP in response to faces than flowers at Pz (male: $p < 0.01$; female: $p < 0.001$) (Fig. 3.5). However, at Cz site, females showed significantly greater late LPP in response to faces than in response to flowers ($p < 0.001$), but males did not (Fig. 3.5).

Separate analysis for comparisons between males and females in each stimuli type showed that there was no significant difference between males and females in late LPP at Cz or Pz (all $p > 0.05$) (Fig. 3.5).

3.3.3 Behavioral responses

Response accuracies and reaction time

Table 3.2 shows response accuracies and reaction time. Response accuracies showed a significant main effect of Stimuli ($F(1,30) = 15.4$, $p < 0.001$), indicating that response accuracy was lower in response to faces than to flowers (Table 3.2). No significant main effect of Gender, or reliable interaction, was seen. Reaction times also showed a significant main effect of Stimuli ($F(1,30) = 157.8$, $p < 0.001$), suggesting that reaction times were longer in response to faces than to flowers (Table 3.2). No significant main effect of Gender, or reliable interaction, was seen.

Table 3.2 Response accuracies and reaction time

	Response accuracies (%)		Reaction time (ms)	
	Males	Females	Males	Females
Faces	99.3 (1.8)	99.0 (1.0)	428.4 (70.9)	419.3 (72.6)
Flowers	99.8 (0.6)	99.7 (0.8)	330.6 (40.9)	323.6 (36.6)

Note. *n* = 32 (Male: 17; Female: 15),
Mean (Standard deviation)

Subjective ratings

Table 3.3 shows subjective ratings. Subjective ratings showed a significant main effect of Stimuli (valence: $F(1, 30) = 37.0$, arousal: $F(1, 30) = 51.8$, all $p < 0.001$), indicating that faces were more unpleasant and more arousing stimuli than flowers (Table 3.3). No significant main effect of Gender, or reliable interaction, was seen.

Table 3.3 Subjective ratings

	Valance		Arousal	
	Males	Females	Males	Females
Faces	-0.1 (0.3)	-0.3 (0.5)	1.4 (1.1)	1.2 (0.7)
Flowers	0.8 (0.8)	1.0 (0.8)	0.2 (0.8)	-0.4 (1.0)

Note. *n* = 32 (Male: 17; Female: 15),
Mean (Standard deviation)
Valance: 'very pleasant', 3; 'very unpleasant' -3
Arousal: 'very aroused' 3; 'very relaxed' -3

3.4 Discussion

In this chapter, I investigated whether there is gender difference in LPP elicited by discriminating emotional facial expressions (happy or angry) and flower colors (yellow or purple), even when empathy trait does not differ between genders.

Gender differences in response to discrimination of facial expressions

The most important finding of the present study was that females showed greater LPP peak than males in response to faces (Fig. 3.4). This result is in line with previous ERP studies (Guillem & Mograss, 2005; Orozco & Ehler, 1998; Proverbio et al., 2009). As mentioned in 1.2.3 Event-related potential (ERP), LPP reflects the motivational significance of stimuli (Weinberg et al., 2013; Lang et al., 1997; Schupp et al., 2000), and the present finding thus indicates that females pay more attention to faces than males. Furthermore, the present result suggests that gender differences exist not only in processing relatively weak changes of facial expressions (i.e., from neutral face to happy or sad face (Orozco & Ehler, 1998)), but also in processing relatively strong changes of facial expressions (i.e., from angry face to happy face and vice versa).

As shown in the Chapter 2, in response to human faces, LPP amplitude is affected by the empathy trait of individuals. However, to the best of my knowledge, the present study is the first to consider the empathy trait of male and female participants when investigating gender differences in the LPP response elicited by human faces. Whether the greater LPP amplitude elicited by faces in females than in males was because of empathy trait or gender *per se* had thus remained unclear. The present results suggest that females pay attention to human faces more than males in the late stage of face processing, even when no gender difference in empathy trait is present. Thus, I argue that gender difference in LPP amplitude elicited by faces results from gender *per se* more than empathy trait of individuals.

This might be related to biological specialization between males and females, such as physical attributes (size, strength, and speed) of males and reproductive capacity of females (Wood & Eagly, 2002). For example, females are weaker physically than males and thus it might be important for females to discriminate facial expression (especially, negative facial expressions such as angry and afraid expressions) of others and avoid a dangerous situation. In addition, females have been caretaker of children in many cultural areas except a few cultural areas and thus it might be more important for females to discriminate facial expressions of baby who cannot express his/her emotion with language. Thus, increased attention to face in females is thought to be related with survival of human beings.

Gender differences in response to discrimination of flower colors

Above all, the analysis of LPP provided evidence that both males and females showed generally greater amplitude of LPP (LPP peak, early LPP, and late LPP) at the central and parietal areas when discriminating facial expressions than when discriminating flower colors (Fig. 3.3; Fig. 3.4; Fig. 3.5). This indicates that both males and females pay more attention to discrimination of facial expressions than discrimination of flower colors. In addition, response accuracies and reaction times did not show gender difference (Table 3.2; Table 3.3), suggesting that discrimination of facial expressions was more difficult than discrimination of flower colors in both males and females.

However, I also found some gender differences in LPP responses to discrimination of facial expressions and discrimination of flower colors. First, there was gender difference in LPP peak in response to discrimination of facial expressions, not in response to discrimination of flower colors (Fig. 3.4). This suggests that gender differences are greater in attention to stimuli containing human elements than stimuli not containing human elements, supporting the interpretation of previous studies (Han et al., 2008; Proverbio et al., 2009). Second, late LPP was greater in response to discrimination of facial expressions than in discrimination of flower colors at the central area in females, not in males (Fig. 3.5). Late LPP (>600 ms) has been reported to reflect more elaborate and top-down processing of stimuli than early LPP (<600 ms) (Weinberg & Hajcak, 2011; Weinberg et al., 2012; Olofsson et al., 2008). The analysis of late LPP thus suggests that females pay closer attention to face than to non-face stimuli in the late stage of attention, whereas males do not. This supports the view that females process information in a more detailed manner (Gullem & Mograss, 2005).

However, there is a limitation in these interpretations, since results of LPP responses and behavioral responses showed that there were many differences between discrimination of facial expressions and discrimination of flower colors (refer to 2.4.Discussion). Thus, in future study, stimuli with the same degree of arousal as human faces need to be used as non-face stimuli, in order to support the interpretation that gender differences are greater in attention to stimuli containing human elements than stimuli not containing human elements.

Limitations

Adding to difference between discrimination of facial expressions and discrimination of flower colors mentioned above, other limitations exist in the present chapter. First, I could not analyze ERP responses elicited by male and female faces separately, due to the limited average number of trials. Second, I found a gender difference in the same stimuli only in LPP peak amplitude, not in mean amplitude (i.e., averaging amplitude in specific temporal windows; defined as early LPP and late LPP in the present study). Although both peak and mean amplitude have been used in ERP studies, some authors (e.g., Luck, 2005) have argued that peak amplitude is a less credible index than mean amplitude. The gender difference in LPP shown in the present chapter might thus be considered weak.

Conclusion

In conclusion, the present results of LPP amplitude provided evidence that both males and females pay more attention faces than to non-face stimuli, but this tendency is more dominant in females than in males. This extends the findings of previous studies that females are more sensitive than males to stimuli with human elements. In addition, in the present study, there was no gender difference in empathy trait. Thus, gender difference in attention to face seems to result from gender *per se* more than empathy trait of individuals.

Chapter 4
Effect of empathy trait on attention to various facial expressions

4.1 Introduction

The results of Chapter 2 showed that there was a positive relationship between Interpersonal Reactivity Index (IRI) and late positive potential (LPP) elicited by discriminating happy and angry faces. This suggests that individuals with high empathy trait, compared with those with low empathy trait, might pay attention to happy and angry facial expressions.

However, in Chapter 2, I could not analyze event-related potential (ERP) response to happy and angry faces separately (refer to 2.4 Discussion). Thus, whether there is relationship between empathy trait and LPP elicited by only happy faces (or angry faces) was unclear. According previous studies, happy faces could be social rewards for observers (O'Doherty, 2004), whereas angry faces could be cue of social threat (Chakrabarti et al., 2006). Thus, it seems to be necessary to analyze LPP elicited by happy and angry faces separately and investigate relationships between empathy trait and those LPP responses.

Moreover, basic facial expressions have generally been thought to comprise the following six expressions: happiness; anger; surprise; fear; sadness; and disgust (refer to Ekman and Friesen, 1971). However, to the best of my knowledge, only one study (Chakrabarti et al., 2006) examined the relationship between empathy trait and attention to more than four expressions, using neurotypical adult participants as subjects. In this study (Chakrabarti et al., 2006), the empathy trait of participants was measured using the Empathy quotient (EQ, Baron-Cohen & Wheelwright, 2004), with participants observing short movie clips of happy, angry, sad and disgusted faces. The results showed that, across all facial expressions, empathy trait correlated positively with brain activity (Chakrabarti et al., 2006), suggesting that individuals with high empathy trait pay attention to those facial expressions more than those with low empathy trait. However, it is still unclear whether there is a relationship between IRI and LPP responses to various facial expressions such as surprised, afraid, or sad faces.

It seems particularly important to investigate empathy trait and ERP responses elicited by surprised faces, since surprised facial expression can be interpreted as both positive and negative expressions, depending on context (Kim et al., 2003; Neta et al., 2009; Neta et al., 2011). Thus, surprised facial expression is different from other facial expressions such as happy, angry, afraid, and sad facial expressions, which can be discriminated to pleasant or unpleasant facial expressions clearly.

In addition, I focused not only on LPP component, but also on N170 component of ERP in this Chapter. N170 is called a face-selective component, as the negative peak is shown in the posterior temporal areas around 170 ms after face onset (Bentin et al., 1996; Campanella et al., 2000; Eimer & Holmes, 2002; Holmes et al., 2003; Taylor et al., 1999). More negative N170 appears to reflect increased attention to faces, as N170 is more negative when faces are attended than when faces are presented outside the attentional focus (Holmes et al., 2003). I thus hypothesized that individuals with high empathy trait might show more negative N170 than those with low empathy trait, if there is difference in very early stage of processing of various facial expressions between individuals with high empathy trait and low empathy trait.

In this chapter, I thus aimed to investigate the relationships between the IRI and ERP responses (N170 and LPP) to five facial expressions (happy, angry, surprised, afraid, and sad). I did not present disgusted facial expression as stimuli, since it is less interpersonal facial expression than other facial expressions (Chakrabarti et al., 2006) Participants discriminated those five facial expressions from emotionally neutral faces under an oddball paradigm. I predicted that individuals with high empathy trait would pay more attention to all facial expressions (happy, angry, surprised, afraid, and sad) and may thus show a more negative N170 and a more positive LPP compared to individuals with low empathy.

4.2 Methods

Participants

Twenty-two Japanese university or graduate school students participated in the study (12 men, 10 women; age range, 21 to 28 years; all right-handed). Participants had normal or corrected-to-normal color vision and were not using prescription medications. They filled out the Japanese version (Sakurai, 1998) of the IRI (Davis, 1983) using responses on a scale of 1 (‘does not describe me well’) to 4 (‘describes me very well’). Written informed consent was obtained from all participants prior to participation. All study protocols were approved by the ethics committee in the Department of Design at Kyushu University, Japan.

As progesterone levels have been reported to increase LPP amplitude during the period from 4-10 days before menstruation (Johnson & Wang, 1991), female participants participated in the experiment during a time that excluded this period.

Stimuli and procedure

Images of 12 adult humans (6 men, 6 women) showing six types of facial expression (neutral, happy, angry, surprised, afraid, and sad) were taken from the Karolinska Directed Emotional Faces (Lundqvist et al., 2011) for a total of 72 images. All images were edited to 300 × 400 pixels and presented in the centre of a black screen (17-inch monitor, 1,024 × 768 resolution).

Five blocks of oddball tasks were conducted during ERP recording. In each block, target stimuli were happy, angry, surprised, afraid, or sad faces, while non-target stimuli were emotionally neutral faces in all blocks (Table 4.1). Participants were instructed to press a key with the right hand as soon as they saw the target. Each block consisted of 96 trials, during which the target was presented 25% of the time (24 trials).

Table 4.1 Target and non-target stimuli

Block	Target (25%)	Non-target (75%)
1	Happy faces	Neutral faces
2	Angry faces	Neutral faces
3	Surprised faces	Neutral faces
4	Afraid faces	Neutral faces
5	Sad faces	Neutral faces

After a cross shape was presented for 500 ms, a target or non-target image was presented for 800 ms (interstimulus interval, 1,000 ms) (Fig. 4.1). Targets were never presented on two consecutive trials.

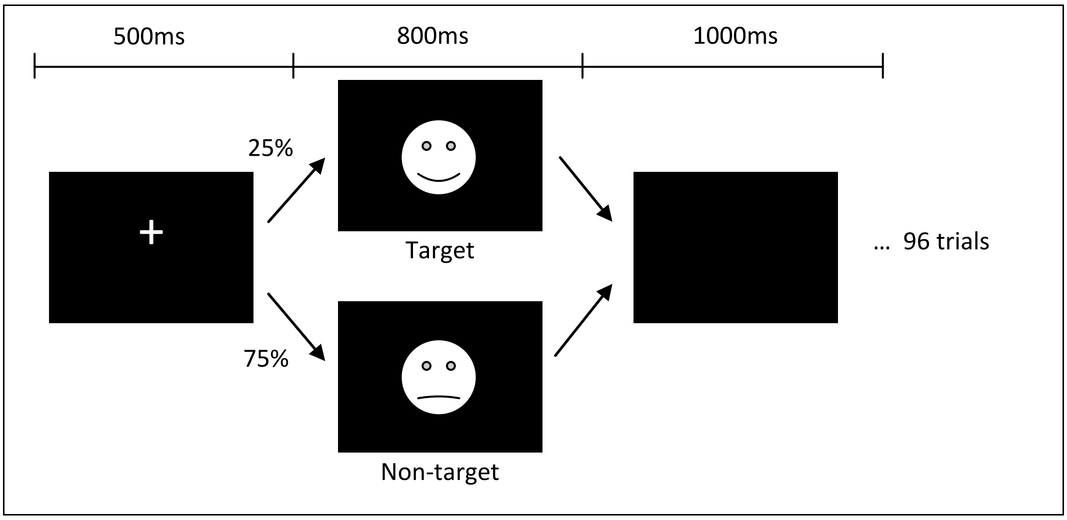

Fig. 4.1 Experimental procedure (block 1). After cross mark (500 ms), target of non-target was presented (800 ms). Target (happy face) was presented in 25% probability and non-target (neutral face) was presented in 75% probability. The faces in this figure were drawn only for illustrative purposes, because Karolinska Directed Emotional Faces (Lundqvist et al., 2011) are not intended for publication.

After oddball tasks, participants assessed the valence and arousal of images based on a visual analog scale (VAS) (for valence, 0 cm indicated 'very pleasant', the middle part of the scale indicated 'neutral', and 10 cm indicated 'very unpleasant'; for arousal, 0 cm indicated 'very aroused, the middle part of the scale indicated 'neutral', and 10 cm indicated 'very relaxed'). I scored 0 cm as -10 points and 10 cm as 10 points.

ERP measurements and analysis

As seen in Fig. 4.2, electroencephalography (EEG) was recorded at the Fz (medial frontal), Cz (medial central), Pz (medial parietal), T5 (left posterior temporal), and T6 (right posterior temporal) sites based on the International 10 to 20 system (Towle et al., 1993) with averaged ears as reference using a Polymate AP1532 system (TEAC, Tokyo, Japan). Electrooculography (EOG) was recorded to detect blinking with electrodes above and below the right eye. All electrode impedances were below 10 kΩ.

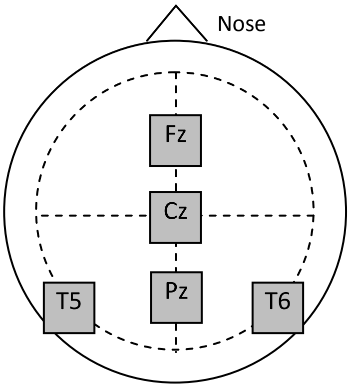

Fig. 4.2 Location of electrodes

EEG signals were digitized at a sampling rate of 500 Hz and amplified (band pass, 1 to 30 Hz) using the EMSE Suite (Source Signal Imaging, San Diego, CA, USA). I excluded trials containing artifacts > 50 μV and trials during which the subject did not show any response. Target stimulus presentation of -200 to 800 ms was averaged (baseline: stimulus presentation of -200 to 0 ms) for each facial expression (happy, angry, surprised, afraid, and sad). The mean number of trials was 20.6 (SD = 2.3) for happy faces, 20.0 (SD = 3.6) for angry faces, 21.3 (SD = 3.2) for surprised faces, 20.2 (SD = 3.4) for afraid faces, and 20.1 (SD = 2.9) for sad faces.

N170 was calculated as mean amplitude within 140 to 200 ms at the T5 and T6 sites (Fig. 4.3(A)). LPP was calculated as mean amplitude within 300 to 600 ms (for early LPP) and 600 to 800 ms (for late LPP) at the Fz, Cz, and Pz sites (Fig. 4.3(B)).

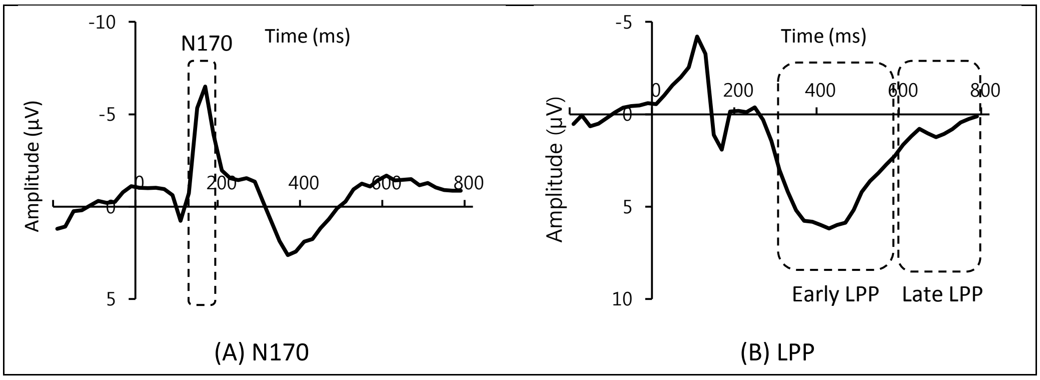

Fig. 4.3 Calculation of ERP response

Statistical analysis

For ERP responses, I conducted repeated-measures ANOVA with Emotion (happy, angry, surprised, afraid, and sad) and Site (N170: T5 and T6; LPP: Fz, Cz, and Pz) as within-subject factors. I then correlated IRI score with N170 at T6, early LPP at Pz, and late LPP at Fz (Pearson's correlation coefficient) (for details, refer to 4.3 Results). For behavioral data (response accuracies, reaction times, and subjective ratings), I conducted repeated-measures ANOVA with Emotion as a within-subject factor and then correlated IRI score with behavioral data (Pearson's correlation coefficient).

Statistical significance was accepted at the 5% level ($P < 0.05$) (SPSS, Chicago, IL, USA). The Greenhouse-Geisser correction was applied where sphericity was violated. I analyzed male and female data together, since no significant sex differences in IRI score were apparent (for details, see Chapter 5).

4.3 Results

4.3.1 Empathy trait

Table 4.2 shows IRI score of participants.

Table 4.2 IRI scores

	Range	Mean (SD)
Total score	54 to 96	79.0 (10.5)
Perspective taking	13 to 27	20.5 (3.9)
Fantasy	11 to 28	19.6 (4.5)
Empathic concern	14 to 25	20.1 (2.8)
Personal distress	13 to 25	18.8 (3.4)

Note. $n = 22$

SD: standard deviation

4.3.2 ERP responses

N170

No significant main effect of Emotion or interaction was seen for N170. The main effect of Site was significant ($F(1, 21) = 12.51$, $p < 0.01$), suggesting that N170 is significantly more negative at T6 than at T5. I thus correlated N170 at T6 site (Fig. 4.4) and IRI score. Mean amplitude of N170 elicited at T6 was -4.8 μV (SD = 2.6) for happy faces, -4.9 μV (SD = 2.5) for angry faces, -4.9 μV (SD = 3.1) for surprised faces, -5.0 μV (SD = 2.4) for afraid faces, and -4.5 μV (SD = 2.5) for sad faces.

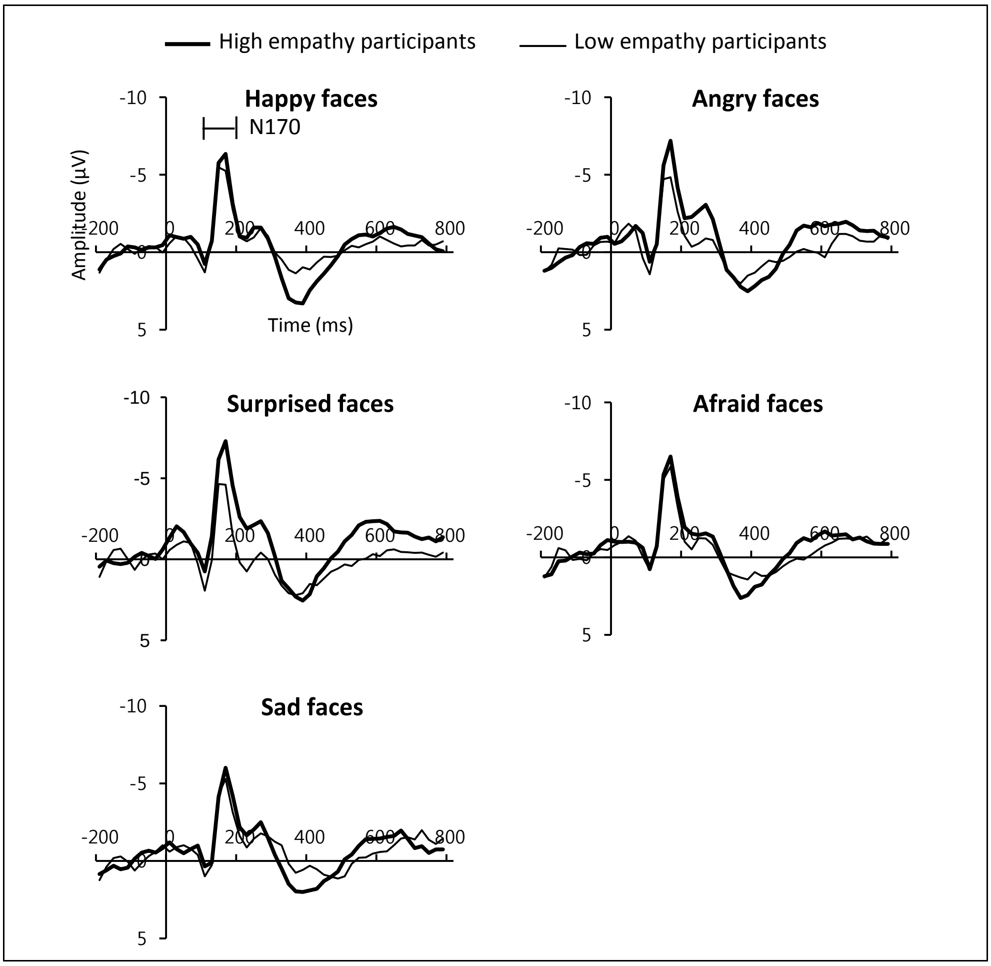

Fig. 4.4 Grand-averaged ERP waveforms elicited at T6. High empathy participants (thick line, n = 12, range of total IRI scores: 80 to 96) and low empathy participants (thin line, n = 10, range of total IRI scores: 54 to 78) were labelled only for illustrative purposes.

As seen in Table 4.3, IRI total scores correlated significantly and negatively with N170 elicited by angry ($p < 0.05$) and surprised faces ($p < 0.01$, Fig. 4.5). The Perspective taking scale correlated significantly and negatively with N170 elicited by happy ($p < 0.05$) and surprised faces ($p < 0.05$) (Table 4.3). Empathic concern scale correlated significantly and negatively with N170 elicited by happy ($p < 0.05$), angry ($p < 0.01$), surprised ($p < 0.01$), and afraid faces ($p < 0.05$) (Table 4.3).

Table 4.3 Correlations between IRI score and N170 (T6)

N170 \ IRI	Total score	Perspective taking	Fantasy	Empathic concern	Personal distress
Happy faces	-0.30	-0.50*	0.00	-0.43*	0.01
Angry faces	-0.44*	-0.32	-0.16	-0.63**	-0.23
Surprised faces	-0.61**	-0.51*	-0.32	-0.71**	-0.26
Afraid faces	-0.33	-0.18	-0.29	-0.44*	-0.07
Sad faces	-0.32	-0.33	-0.14	-0.36	-0.11

Note. *n* = 22

*p < 0.05, p < 0.01**, Pearson correlation

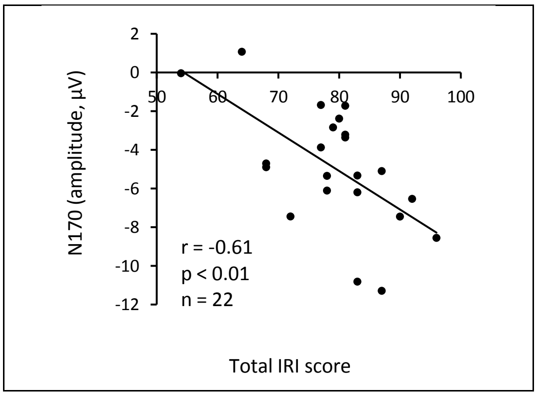

Fig. 4.5 Correlation between IRI score and N170 (T6). Total IRI score correlated with N170 elicited by surprised faces negatively and significantly (Pearson's correlation, r = 0.61, p < 0.01).

Early LPP

For early LPP, no significant main effect of Emotion or interaction was evident. A main effect of Site was significant (F (1.59, 33.32) = 46.78, $p < 0.001$), suggesting that early LPP is significantly more positive at Pz than at Fz ($p < 0.001$), and Cz ($p < 0.05$). I thus correlated early LPP at Pz (Fig.4.6) and IRI score. Mean amplitude of early LPP elicited at Pz was 4.7 μV (SD = 2.1) for happy faces, 5.1 μV (SD = 1.7) for angry faces, 5.3 μV (SD = 1.4) for surprised faces, 5.3 μV (SD = 1.7) for afraid faces, and 5.3 μV (SD = 1.8) for sad faces.

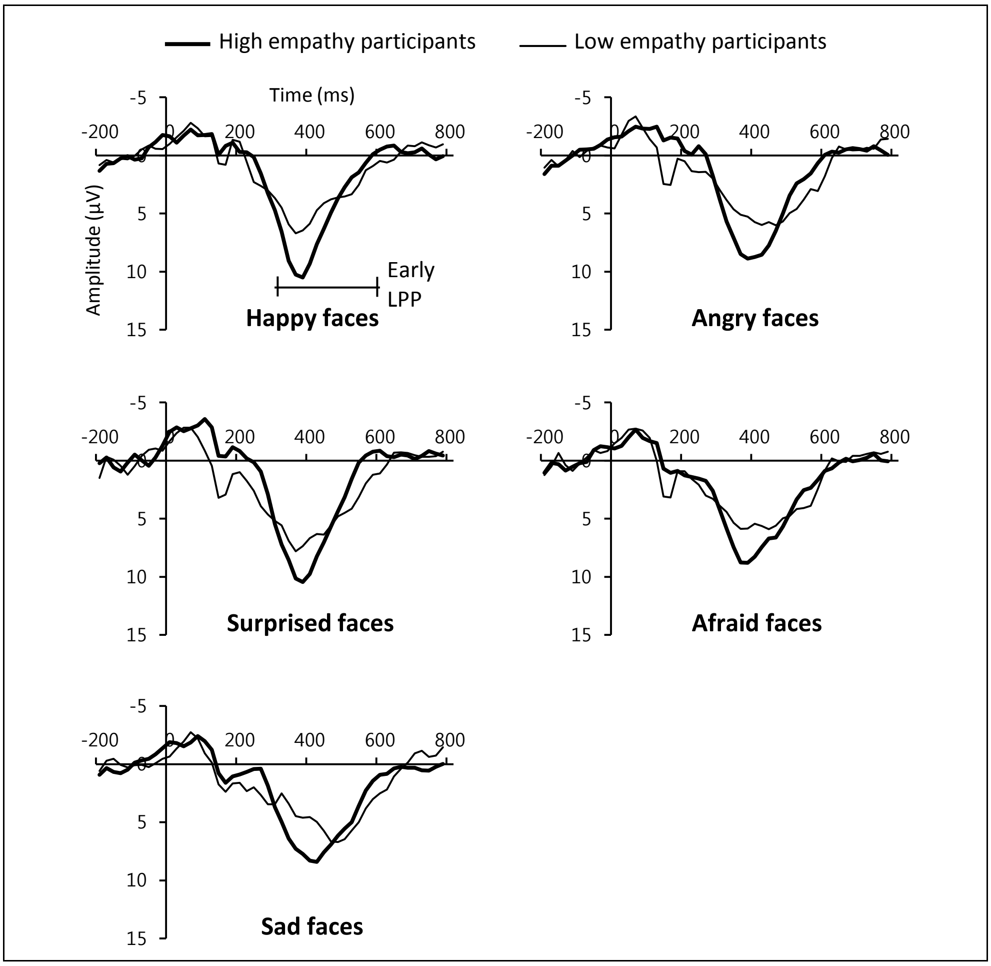

Fig. 4.6 Grand-averaged ERP waveforms elicited at Pz. High empathy participants (thick line, n = 12, range of total IRI scores: 80 to 96) and low empathy participants (thin line, n = 10, range of total IRI scores: 54 to 78) were labelled only for illustrative purposes.

As seen in Table 4.4, the Perspective taking scale showed significant, positive correlations with early LPP elicited by angry ($p < 0.05$) and afraid faces ($p < 0.05$).

Table 4.4 Correlations between IRI score and early LPP (Pz)

Early LPP \ IRI	Total score	Perspective taking	Fantasy	Empathic concern	Personal distress
Happy faces	0.31	0.29	0.18	0.17	0.24
Angry faces	0.34	0.45*	0.12	0.17	0.21
Surprised faces	0.04	0.25	-0.10	-0.05	-0.01
Afraid faces	0.38	0.49*	0.21	0.26	0.10
Sad faces	0.27	0.41	-0.01	0.18	0.20

Note. $n = 22$

*$p < 0.05$, Pearson correlation

Late LPP

For late LPP, no significant main effect of Emotion or interaction was seen. A main effect of Site was significant (F (1.36, 28.63) = 33.61, $p < 0.001$), suggesting that late LPP is significantly more positive at Fz than at Cz ($p < 0.01$) and Pz ($p < 0.001$). I thus correlated late LPP at Fz (Fig.4.7) and IRI score. Mean amplitude of late LPP elicited at Fz was 1.7 μV (SD = 1.3) for happy faces, 1.7 μV (SD = 1.6) for angry faces, 1.4 μV (SD = 2.0) for surprised faces, 1.8 μV (SD = 2.0) for afraid faces, and 1.7 μV (SD = 2.1) for sad faces.

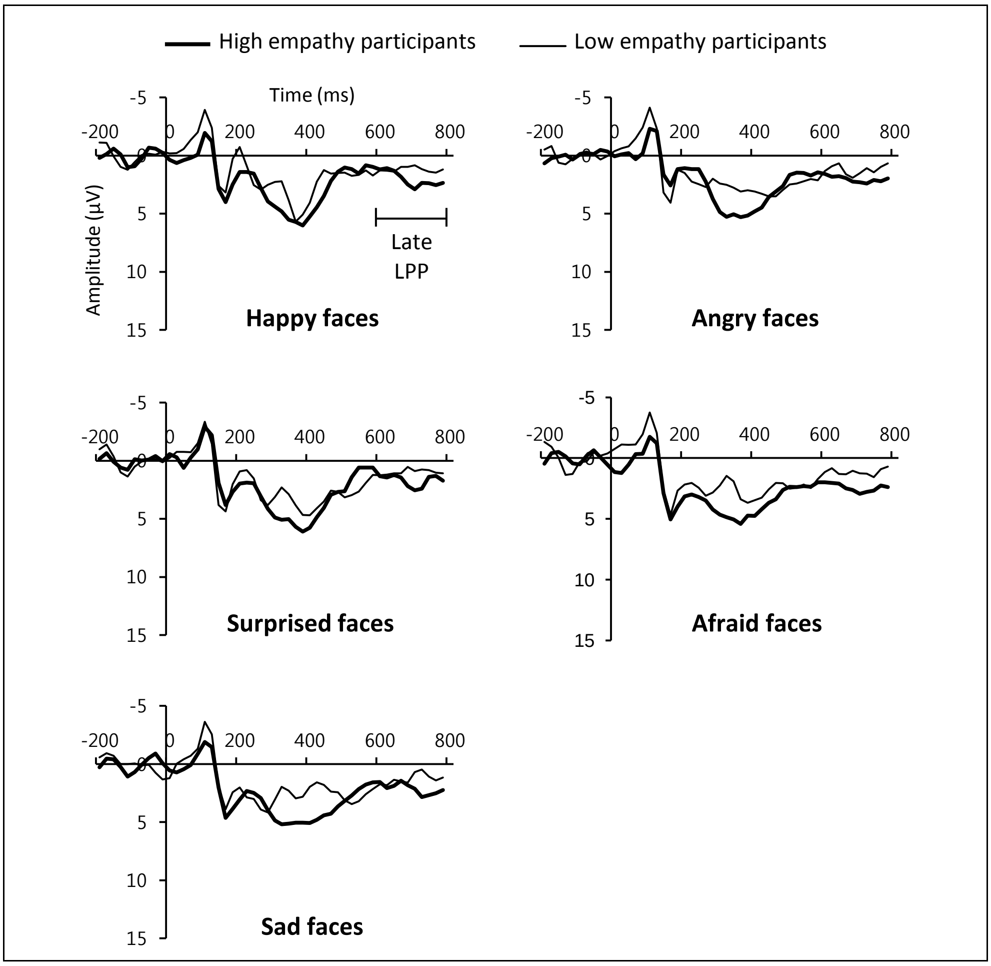

Fig. 4.7 Grand-averaged ERP waveforms elicited at Fz. High empathy participants (thick line, n = 12, range of total IRI scores: 80 to 96) and low empathy participants (thin line, n = 10, range of total IRI scores: 54 to 78) were labelled only for illustrative purposes.

As seen in Table 4.5, IRI total score correlated significantly and positively with late LPP elicited by happy ($p < 0.05$), angry ($p < 0.05$), surprised ($p < 0.05$, Fig. 4.8), and sad faces ($p < 0.05$). The Perspective taking scale correlated significantly and positively with late LPP elicited by happy ($p < 0.05$), surprised ($p < 0.01$), and afraid faces ($p < 0.05$) (Table 4.5). The Fantasy scale correlated significantly and positively with late LPP elicited by angry faces ($p < 0.05$) (Table 4.5). The Empathic concern scale correlated significantly and positively with late LPP elicited by happy faces ($p < 0.05$) (Table 4.5).

Table 4.5 Correlations between IRI score and late LPP (Fz)

IRI / Late LPP	Total score	Perspective taking	Fantasy	Empathic concern	Personal distress
Happy faces	0.49*	0.43*	0.39	0.46*	0.11
Angry faces	0.49*	0.27	0.48*	0.31	0.28
Surprised faces	0.44*	0.54**	0.23	0.31	0.16
Afraid faces	0.42	0.43*	0.21	0.39	0.17
Sad faces	0.44*	0.38	0.31	0.34	0.22

Note. $n = 22$
*$p < 0.05$, $p < 0.01$**, Pearson correlation

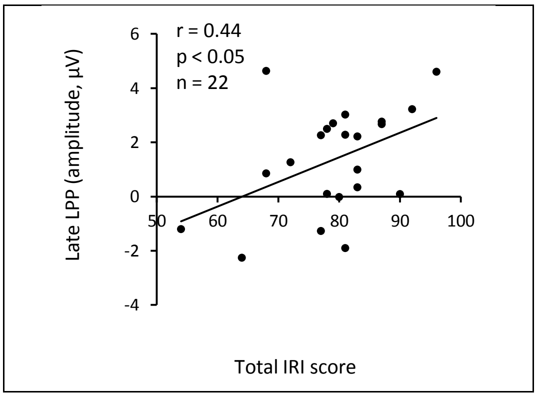

Fig. 4.8 Correlation between IRI score and late LPP (Fz). Total IRI score correlated with late LPP elicited by surprised faces positively and significantly (Pearson's correlation, $r = 0.44$, $p < 0.05$).

4.3.3 Behavioral responses

Response accuracies and reaction time

Table 4.6 shows response accuracies and reaction time. For response accuracies, a significant main effect was seen for Emotion ($F(4, 84) = 4.68$, $p < 0.01$), showing that response accuracies were highest in response to surprised faces and lowest in response to sad faces (Table 4.6). Response accuracies did not show any significant correlation with IRI (all $p > 0.05$). Reaction times also showed a significant main effect of Emotion ($F(4, 84) = 11.67$, $p < 0.001$), appearing shortest in response to surprised faces and longest in response to sad faces (Table 4.6). Reaction times did not show a significant correlation with IRI (all $p > 0.05$).

Table 4.6 Response accuracies and reaction time

	Response accuracies (%)	Reaction time (ms)
Happy faces	99.2 (0.8)	396.4 (68.6)
Angry faces	98.6 (1.7)	413.0 (51.5)
Surprised faces	99.3 (0.8)	386.8 (52.2)
Afraid faces	99.1 (1.1)	412.2(66.3)
Sad faces	98.2 (1.7)	440.3(56.9)

Note. *n* = 22
Mean (Standard deviation)

Subjective ratings

Table 4.7 shows results of subjective rating. For valance, a significant main effect was seen for Emotion (F(4, 84) = 76.81, p < 0.001), showing that happy face was rated as the most pleasant expression, whereas angry face was rated as the most unpleasant expression (Table 4.7). For arousal, a significant main effect was seen for Emotion (F(2.92, 61.27) = 15.87, p < 0.001), showing that happy face was rated as the most arousing face, whereas sad face was rated as the least arousing face (Table 4.7). Subjective rating did not show any significant correlation with IRI (all p > 0.05).

Table 4.7 Subjective ratings

	Valance	Arousal
Happy faces	5.8 (2.7)	5.5 (1.9)
Angry faces	-5.0 (2.2)	5.2 (2.6)
Surprised faces	-0.1 (1.5)	4.2 (2.9)
Afraid faces	-3.2 (2.5)	3.1 (3.3)
Sad faces	-3.0 (2.7)	0.4 (3.2)

Note. *n* = 22
Mean (Standard deviation)
Valance: ‘very pleasant’, 5; ‘very unpleasant’ -5
Arousal: ‘very aroused’ 5; ‘very relaxed’ -5

4.4 Discussion

In this chapter, I aimed to clarify the relationship between empathy trait and attention responses to five facial expressions (happy, angry, surprised, afraid, and sad), by measuring N170 and LPP components as indices of attention.

Empathy trait and N170

In the present study, clear N170 was elicited in response to all five facial expressions - happy, angry, surprised, afraid, and sad faces (Fig.4.4). In addition, N170 was more negative at the right posterior temporal area than at the left posterior temporal area. This is in line with previous findings (Bentin et al., 1996; Campanella et al., 2000; Taylor et al.,

1999) and supports the idea of Campanella et al. (2000) that the perception of human faces is associated with the right posterior temporal area. However, N170 was not different depending on facial expressions in the present study. Some previous studies have reported that N170 is modulated by facial expression (Luo et al., 2010; Zhang et al., 2013), while others have not found this association (Eimer et al., 2003; Herrmann et al., 2002). The present study supports the latter findings (Eimer et al., 2003; Herrmann et al., 2002), suggesting that N170 is not different among facial expressions in the task of discriminating emotional facial expressions from emotionally neutral facial expressions.

Overall, N170 showed negative correlations with IRI for happy, angry, surprised, and afraid faces (Table 4.3). The present finding thus suggests that individuals with high empathy trait pay attention more than those with low empathy from very early stage (around 170 ms after face onset), not only to angry face (Soria et al., 2012), but also to happy, surprised, and afraid faces. However, in response to sad faces, no significant correlation between IRI and N170 was seen. This might be because sad faces were the most difficult facial expression to discriminate from emotionally neutral faces in the present experiment, given that response accuracy was lowest and reaction time was longest in response to sad faces. In addition, sad faces were rated as the least arousing facial expression. More time might therefore be required for empathy trait to affect the attention processing of sad faces, as N170 reflects the very early stage of attention.

In terms of the relationship between each subscale of IRI and N170, the present study showed that N170 correlates with perspective taking and empathic concern scales, not with fantasy or personal distress scales (Table 4.3). The perspective taking scale represents attempts to take the perspectives of others, and thus reflects the cognitive aspect of empathy more than other subscales of IRI (Davis, 1983). Interestingly, the perspective taking scale correlated with happy and surprised faces, but not with angry or afraid faces in the present study. Thus, the cognitive aspect of empathy might affect early processing of faces with positive (happy) or ambiguous (surprised) expressions, rather than with negative expressions (angry or afraid). Meanwhile, the empathic concern scale correlated with happy, angry, surprised, and afraid expressions, partly supporting the previous finding (Soria et al., 2012) of a negative correlation between empathic concern scale and N170 elicited by angry faces. Given that the empathic concern scale assesses the tendency to feel compassion for others (Davis, 1983), a willingness act altruistically might be strongly related to early processing of facial expressions, regardless of the valance of facial expressions.

Empathy trait and LPP

Early LPP (300 to 600 ms) was greater at the medial parietal area (Fig.4.6) than at the frontal and central areas. Typical early LPP was thus thought to be generated in the present experiment, as LPP is generally reported to be maximal at centro-parietal sites (Cuthbert et al., 2000; Schupp et al., 2000; Weinberg & Hajcak, 2011; Amrhein et al., 2004). Meanwhile, late LPP (600 to 800 ms) was greater at the frontal area (Fig.4.7) than at the central and parietal areas, inconsistent with the previous findings mentioned above (Cuthbert et al., 2000; Schupp et al., 2000; Weinberg & Hajcak, 2011; Amrhein et al., 2004). Nonetheless, some ERP studies have reported frontal enhancement of LPP (Hauswald et al., 2011; Leutgeb et al., 2012; Spreckelmeyer et al., 2006). For example, Leutgeb et al. (2011) suggested increased LPP at frontal sites relates to controlled attentional engagement. In addition, late LPP (> 600 ms) seems to reflect elaborate processing of stimuli compared with early LPP (< 600 ms) (Weinberg et al., 2012; Weinberg & Hajcak, 2011). Taken together, frontal enhancement of late LPP is thought to reflect increased cognitive processing of stimuli. I thus suggest that the present oddball task to discriminate facial expressions from emotionally neutral faces as quickly as possible entailed cognitive and sophisticated attention.

In line with my hypothesis, the present study revealed generally positive correlations between IRI and LPP (Table 4.4; Table 4.5), reconfirming the result from Chapter 2. In particular, late LPP correlated with IRI for all facial expressions presented in the present study - happy, angry, surprised, afraid, and sad faces (Table 4.5). I thus suggest that individuals with high empathy pay attention more than those with low empathy in the late stage (600 to 800 ms after face onset) to surprised, afraid, and sad faces, as well as to happy and angry faces (Chapter 2). Given that frontal enhancement of late LPP mirrors cognitive processing as mentioned above, the present study also indicates that empathy trait affects cognitive and voluntary attention for processing of those five facial expressions. Meanwhile, early LPP correlated with IRI only for angry and afraid faces (Table 4.4), unlike late LPP (Table 4.5). Empathy trait seems to relate to obligatory attention only for negative and arousing facial expressions such as angry or afraid faces, as early LPP reflects obligatory capture of attention more than late LPP (Weinberg et al., 2012; Weinberg & Hajcak, 2011).

In addition, late LPP correlated with IRI for sad faces (Table 4.5), while N170 did not (Table 4.3). This finding supports my interpretation mentioned above, suggesting that the processing of sad faces takes longer than the time course of N170.

Investigating each subscale of IRI, the perspective taking scale showed greater correlations with LPP than other subscales of IRI (Table 4.5). The fantasy scale correlated only with late LPP elicited by angry faces and the empathic concern scale correlated only with late LPP elicited by happy faces (Table 4.5). Related to the correlation between the fantasy scale and LPP to angry faces (Table 4.4), the present results are partly consistent with result from the first experiment (for details, refer to Chapter 2), which reported a correlation between the fantasy scale and late LPP elicited by discriminating angry and happy facial expressions (Table 2.4). Attention to angry expressions in others is thus thought to be related to a tendency to be immersed in fiction. However, explaining why late LPP to only angry faces is related with fantasy scale is difficult, as is finding a supportive reason why late LPP to only happy faces correlated with empathic concern scale in the present study. Further research is warranted to explore which aspects of empathy are related to specific facial expressions.

Empathy trait and surprised faces

Surprised expressions revealed stronger correlations between IRI and ERP responses (both N170 and LPP) than the other four facial expressions presented in the present study (Table 4.3; Table 4.5). I suggest that this might be because the valance of surprised faces is ambiguous. Previous studies (Kim et al., 2003; Neta et al., 2009; Neta et al., 2011) have reported that surprised faces can be interpreted as both positive and negative expressions, depending on context. For example, Neta et al. (2011) reported that surprised faces are rated as more positively within the context of positive faces than within the context of angry faces. In the present study, surprised faces were presented only within emotionally neutral faces. The ambiguity of surprised faces might thus have been increased in the present study and individuals with high empathy might pay particular attention to surprised faces, in order to gauge the valance of the surprised face.

Limitations

As mentioned in Chapter 2, I presented Caucasian faces (from Lundqvist et al, 2011) as stimuli, although participants were all Japanese. This might have affected the results, because the participants might have been unacquainted with faces of different races.

Conclusions

I found that IRI correlated negatively with N170 in response to happy, angry, surprised, and afraid faces, but correlated positively with LPP in response to happy, angry, surprised, afraid, and sad faces. This indicates that individuals with high empathy pay greater attention to various facial expressions than those with low empathy, from the very early stage (reflected in N170) to the late stage (reflected in LPP) of facial processing. In addition, the relationship between empathy trait and attention to face was strongest for the surprised facial expression, which might relate to the ambiguity of the surprised facial expression. Furthermore, N170 showed the strongest correlation with the empathic concern subscale among the IRI subscales, which is related to prosocial behaviour. I therefore suggest that among the facets of empathy, the prosocial concern facet in particular affects the increase in attention to facial expressions in the very early stage and *vice versa*.

Chapter 5
Gender difference in attention to various facial expressions

5.1 Introduction

In Chapter 3, I found that females showed greater late positive potential (LPP) peak than males in response to faces, even when there is no gender difference in empathy trait (measured using Interpersonal Reactivity Index, IRI, Davis, 1983) is present. This suggests that increased attention to faces in females results from gender *per se* more than empathy trait of individuals.

However, in Chapter 3, I could investigate gender difference in LPP elicited by only two facial expressions, which are happy and angry expressions. Basic facial expressions have generally been thought to comprise the following six expressions: happiness; anger; surprise; fear; sadness; and disgust (refer to Ekman and Friesen, 1971). Thus, it is necessary to investigate whether there is gender difference in LPP elicited by other facial expressions such as surprised, afraid, or sad facial expression, in order to extend the knowledge of gender difference in attention response to faces.

In addition, I focused not only on LPP component, but also on N170 component of event-related potential (ERP) in this Chapter. N170 is called a face-selective component, as the negative peak is shown in the posterior temporal areas around 170 ms after face onset (Bentin et al., 1996; Campanella et al., 2000; Eimer & Holmes, 2002; Holmes et al., 2003; Taylor et al., 1999). More negative N170 appears to reflect increased attention to faces, as N170 is more negative when faces are attended than when faces are presented outside the attentional focus (Holmes et al., 2003). I thus hypothesized that females might show more negative N170 than males even when there is no gender difference in empathy trait, if gender difference in very early stage of processing of various facial expressions results from gender *per se* more than empathy trait of individuals.

In this chapter, I thus aimed to investigate gender differences in ERP responses (N170 and LPP) elicited by discriminating emotional facial expressions (happy, angry, surprised, afraid, and sad) from emotionally neutral faces, by reanalyzing data from my previous research (Chapter 4). As noted in Chapter 4, male and female participants did not show difference in IRI score, including scores of all subscales (perspective taking; fantasy; empathic concern; and personal distress). I predicted that females, compared with males, would show more negative N170 and more positive LPP when discriminating facial expressions, if gender differences in face processing exist even when empathy trait does not differ between genders.

5.2 Methods

Participants and the experimental procedure were the same as in Chapter 4, except for statistical analysis.

In addition, I calculated LPP peak (most positive potential within 300-800 ms) (Fig. 5.1), in order to investigate gender difference in ERP responses in detail.

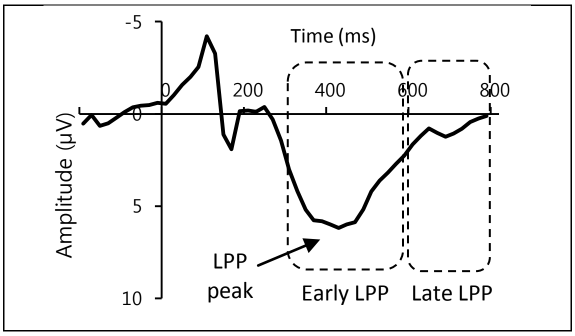

Fig. 5.1 Calculation of ERP response

Statistical analysis

IRI scores were subjected to independent t-test between genders. ERP responses were subjected to repeated-measures ANOVA with Gender as a between-subjects factor and Emotion (happy, angry, surprised, afraid, and sad) and Site (N170: T5 and T6; LPP: Fz, Cz, and Pz) as a within-subject factor. Behavioral responses (response accuracies, reaction times, and subjective ratings) were subjected to repeated-measures ANOVA with Gender as a between-subjects factor and Emotion (happy, angry, surprised, afraid, and sad) as a within-subject factor.

SPSS software (SPSS, Chicago, IL, USA) was used for statistical analysis. Statistical significance was at a level of 5% ($p < 0.05$). The Greenhouse-Geisser correction was applied where sphericity was violated. When the main effect of Gender or an interaction was significant, pairwise comparisons were performed between genders with the Bonferroni correction.

5.3 Results

5.3.1 Empathy trait

Table 5.1 shows empathy trait of male and female participants. There was no significant gender difference in IRI scores ($p > 0.05$, Table 5.1).

Table 5.1 IRI scores

	Mean (SD)		Gender difference[a]	
	Males	Females	t value	p value
Total score	76.6 (11.3)	82.0 (6.3)	-1.35	0.192
Perspective taking	20.1 (4.3)	21.1(3.0)	-0.63	0.536
Fantasy	18.8 (4.5)	20.5 (3.6)	-0.95	0.354
Empathic concern	19.4 (2.7)	20.9 (2.1)	-1.39	0.179
Personal distress	18.3 (3.6)	19.5 (2.6)	-0.92	0.370

Note. n = 22 (Male: 12; Female: 10)
SD: Standard deviation,
[a]Independent t-test (df = 20)

5.3.2 ERP responses

N170

For both of N170, no significant main effect of Gender or Emotion or interaction was seen ($p > 0.05$). The main effect of Site was significant for N170 ($F(1,20) = 12.64$, $p < 0.001$), indicating that N170 was more negative at T6 (Fig. 5.2) than at T5.

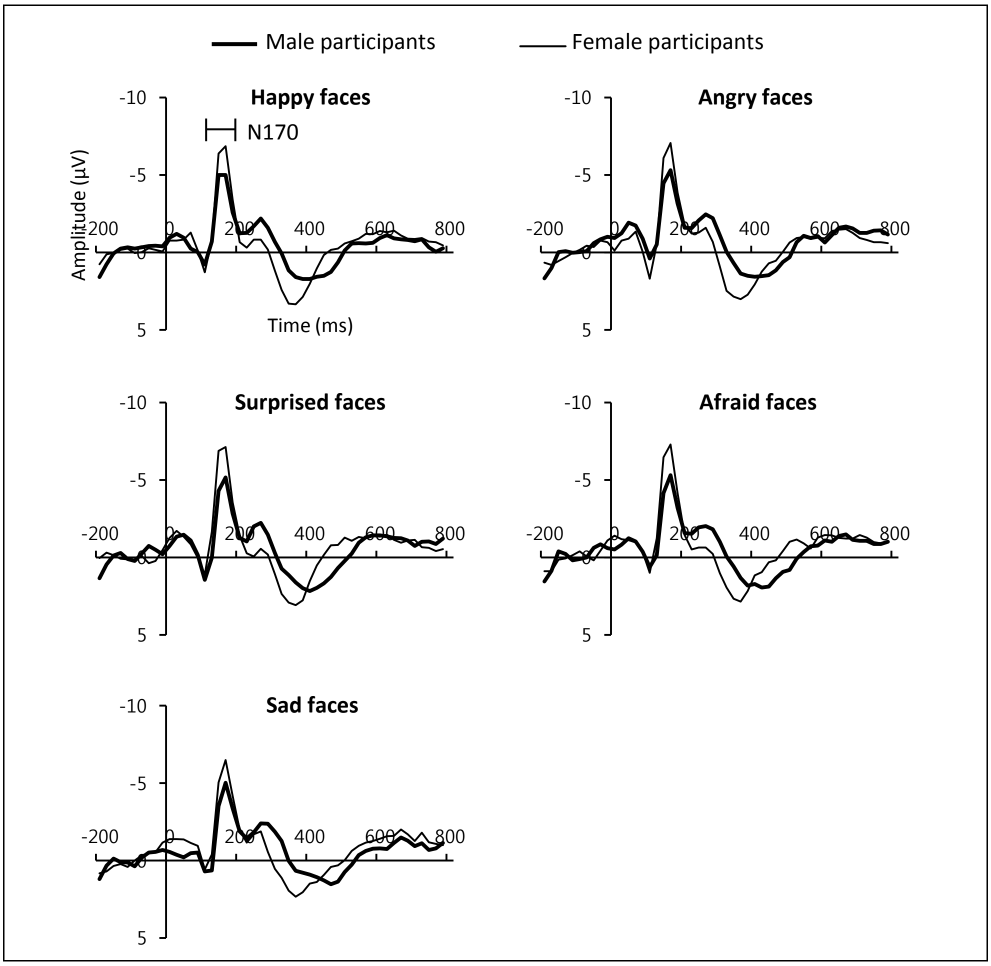

Fig. 5.2 Grand-averaged ERP waveforms elicited at T6. Thick line indicates male participants (n = 12) and thin line indicates female participants (n = 10).

For males, mean amplitude of N170 elicited at T6 was -4.2 µV (SD = 1.8) for happy faces, -4.3 µV (SD = 2.3) for angry faces, -4.1 µV (SD = 3.3) for surprised faces, -4.2 µV (SD = 1.9) for afraid faces, and -4.0 µV (SD = 2.4) for sad faces. For females, mean amplitude of N170 elicited at T6 was -5.6 µV (SD = 3.3) for happy faces, -5.7 µV (SD = 2.7) for angry faces, -5.9 µV (SD = 2.8) for surprised faces, -6.0 µV (SD = 2.7) for afraid faces, and -5.2 µV (SD = 2.7) for sad faces.

Early LPP

For early LPP, no significant main effect of Gender or Emotion or interaction was seen (p > 0.05). The main effect of Site was significant (F(1.6,31.3) = 44.90, $p < 0.001$), indicating that early LPP was more positive at Pz (Fig. 5.3), than Fz and Cz.

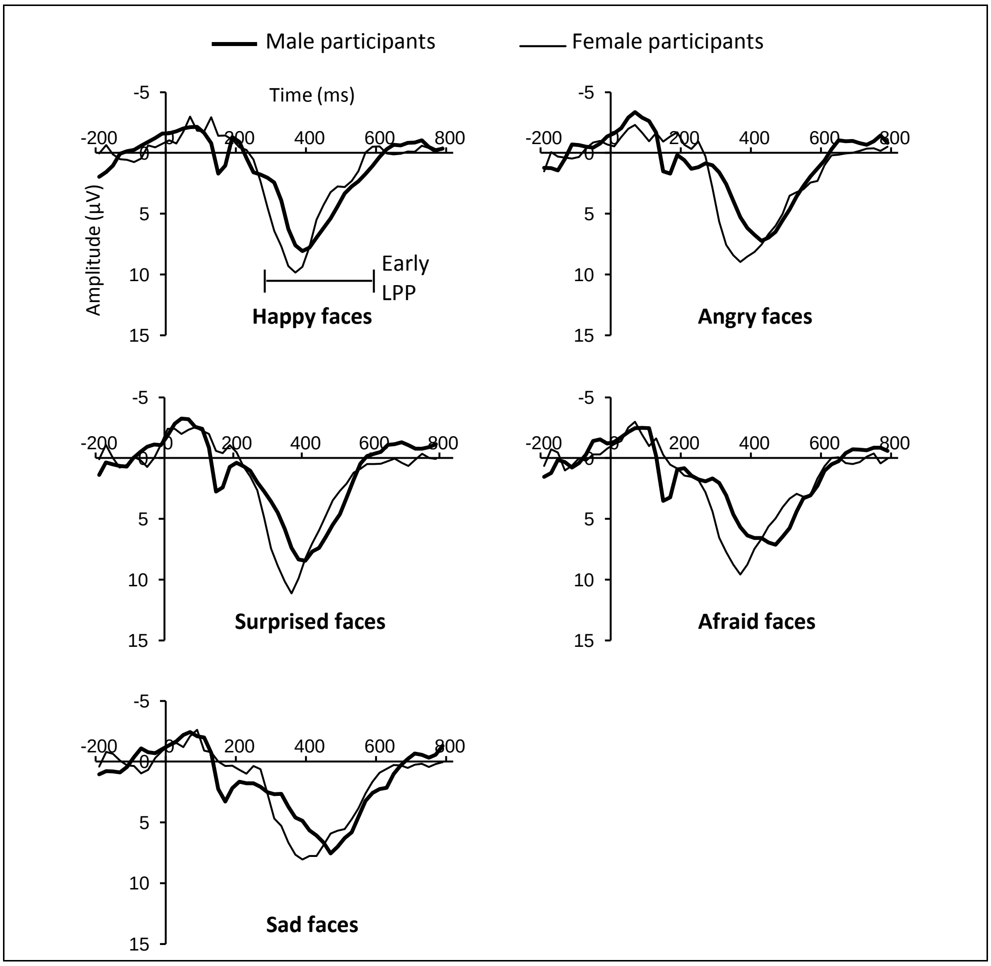

Fig. 5.3 Grand-averaged ERP waveforms elicited at Pz. Thick line indicates male participants (n = 12) and thin line indicates female participants (n = 10).

For males, mean amplitude of early LPP elicited at Pz was 4.7 μV (SD = 1.9) for happy faces, 4.4 μV (SD = 1.5) for angry faces, 5.0 μV (SD = 1.4) for surprised faces, 5.0 μV (SD = 1.5) for afraid faces, and 4.9 μV (SD = 1.9) for sad faces. For females, mean amplitude of early LPP elicited at Pz was 4.8 μV (SD = 2.4) for happy faces, 5.8 μV (SD = 1.7) for angry faces, 5.6 μV (SD = 1.4) for surprised faces, 5.6 μV (SD = 1.9) for afraid faces, and 5.6 μV (SD = 1.6) for sad faces.

LPP peak

LPP peak also showed significant (F(1.42,28.3) = 29.54, $p < 0.001$) main effect of Site, indicating that LPP peak was more positive at Pz (Fig. 5.3) than Fz and Cz. Importantly, for LPP peak, the main effect of Gender was significant (F(1,20) = 5.49, $p < 0.05$), indicating that LPP peak was more positive in females than in males. The main effect of Emotion or interactions was not significant for LPP peak ($p > 0.05$).

Further statistical analysis indicated that females showed significantly more positive LPP peak amplitudes than males in response to angry faces at Fz, Cz, and Pz (all $p < 0.05$), in response to surprised faces at Cz ($p < 0.05$), and in response to sad faces at Fz ($p < 0.001$), Cz ($p < 0.01$), and Pz ($p < 0.05$) (Table 5.2).

Table 5.2 Gender differences in LPP peak

		Mean (SD)		Gender difference[a]	
Site	Facial expressions	Males	Females	F value	*p* value
Fz	Happy faces	8.6 (2.0)	9.1 (3.4)	.23	0.638
	Angry faces	7.5 (1.6)	9.8 (2.9)	5.69	0.027*
	Surprised faces	7.7 (1.4)	10.0 (3.7)	4.07	0.057
	Afraid faces	6.7 (1.8)	9.3 (4.7)	3.22	0.088
	Sad faces	6.7 (1.2)	9.7 (1.9)	19.99	0.000***
Cz	Happy faces	10.6 (4.1)	12.3 (4.4)	.92	0.350
	Angry faces	9.2 (2.5)	12.7 (4.2)	5.78	0.026*
	Surprised faces	9.9 (2.4)	13.4 (4.2)	6.20	0.022*
	Afraid faces	8.9 (2.6)	11.2 (5.0)	1.82	0.192
	Sad faces	8.3 (2.4)	11.9 (3.0)	10.08	0.005**
Pz	Happy faces	10.3 (4.4)	12.1 (4.1)	1.02	0.325
	Angry faces	9.4 (2.4)	12.9 (4.2)	5.87	0.025*
	Surprised faces	10.6 (3.1)	13.1 (3.9)	2.90	0.104
	Afraid faces	9.6 (3.2)	12.5 (5.6)	2.26	0.148
	Sad faces	8.9 (2.9)	12.9 (3.7)	8.06	0.010*

Note. $n = 22$ (Male: 12; Female: 10)
SD: Standard deviation
amplitude (μV)
[a]Follow-up pairwise comparisons, F(1,20), *p < 0.05, ** p < 0.01, *** p < 0.001

Late LPP

For late LPP, no significant main effect of Gender or Emotion or interaction was seen ($p > 0.05$). The main effect of Site was significant ($F(1.4,27.3) = 32.94$, $p < 0.001$), indicating that late LPP amplitude was more positive at Fz (Fig. 5.4) than Cz and Pz.

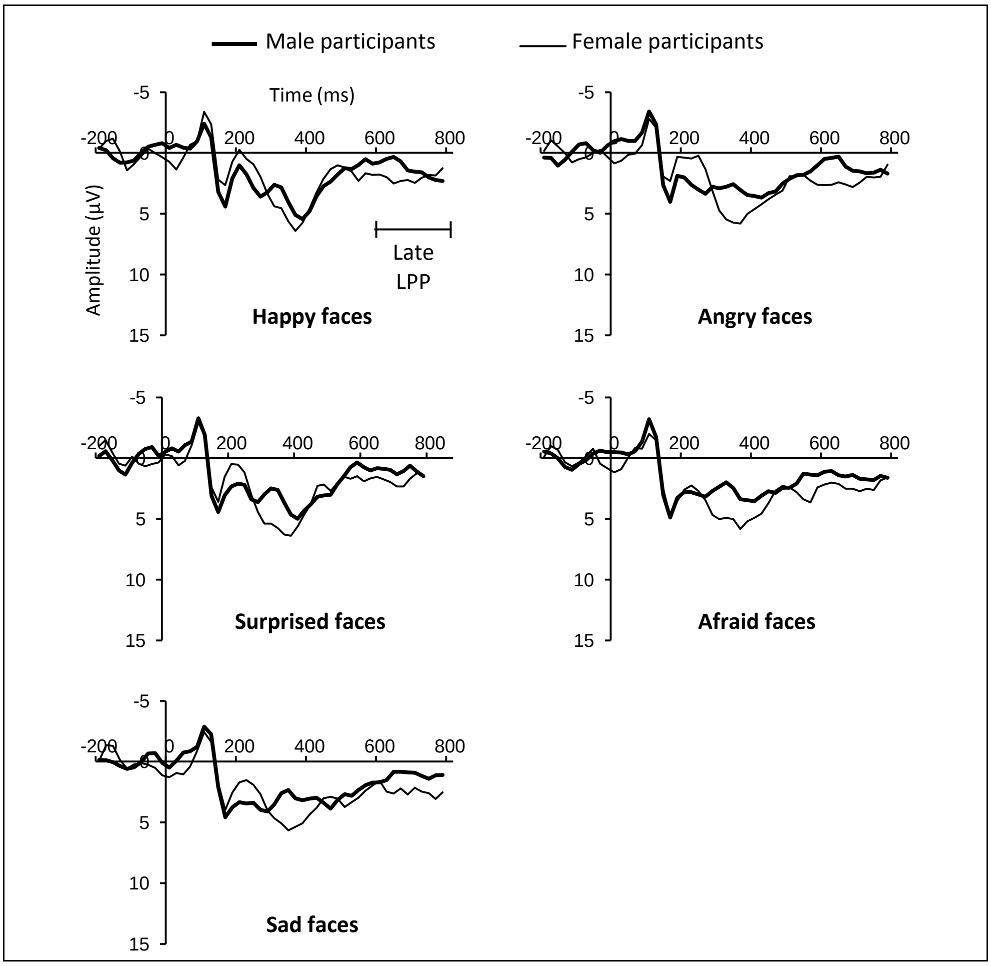

Fig. 5.4 Grand-averaged ERP waveforms elicited at Fz. Thick line indicates male participants (n = 12) and thin line indicates female participants (n = 10).

For males, mean amplitude of late LPP elicited at Fz was 1.3 µV (SD = 1.4) for happy faces, 1.2 µV (SD = 1.6) for angry faces, 1.0 µV (SD = 2.1) for surprised faces, 1.5 µV (SD = 2.1) for afraid faces, and 1.2 µV (SD = 2.1) for sad faces. For females, mean amplitude of late LPP elicited at Fz was 2.0 µV (SD = 1.0) for happy faces, 2.2 µV (SD = 1.5) for angry faces, 1.8 µV (SD = 1.8) for surprised faces, 2.3 µV (SD = 2.0) for afraid faces, and 2.4 µV (SD = 2.0) for sad faces.

5.3.3 Behavioral responses

Response accuracies and reaction time

Table 5.3 shows response accuracies and reaction time. Response accuracies showed a significant main effect of Emotion (F(4,80) = 4.41, p < 0.01), indicating that response accuracy was highest in response to surprised faces and lowest in response to sad faces (Table 5.3). No significant main effect of Gender, or reliable interaction, was seen. Reaction times also showed a significant main effect of Emotion (F(3.0,59.7) = 11.16, p < 0.001), suggesting that reaction times were longest in response to sad faces and shortest in response to surprised faces (Table 5.3). For response accuracies and reaction time, no significant main effect of Gender, or reliable interaction, was seen.

Table 5.3 Response accuracies and reaction time

	Response accuracies (%)		Reaction time (ms)	
	Males	Females	Males	Females
Happy faces	402.2 (45.9)	388.6 (91.1)	99.0 (0.8)	99.6 (0.7)
Angry faces	416.3 (36.0)	409.1 (67.7)	98.0 (2.0)	99.4 (0.7)
Surprised faces	393.5 (50.7)	378.8 (55.7)	99.4 (0.7)	99.3 (0.9)
Afraid faces	420.4 (54.9)	402.3 (79.9)	98.9 (1.2)	99.3 (1.0)
Sad faces	458.8 (46.7)	418.2 (62.3)	97.7 (2.0)	98.8 (1.2)

Note. n = 22 (Male: 12; Female: 10)
Mean (Standard deviation)

Subjective ratings

Table 5.4 shows subjective ratings. Valance rating showed a significant main effect of Emotion (F(4, 80) = 74.70, p < 0.001), indicating that the most pleasant expression was a happy face and the most unpleasant expression was an angry face (Table 5.4). Arousal rating showed a significant main effect of Emotion (F(4, 80) = 15.81, p < 0.001), indicating that the most arousing expression was a happy face and the least arousing expression was an sad face (Table 5.4). For subjective ratings, no significant main effect of Gender, or reliable interaction, was seen.

Table 5.4 Subjective ratings

	Valance		Arousal	
	Males	Females	Males	Females
Happy faces	6.3 (2.1)	5.3 (3.3)	5.7 (2.0)	5.2 (1.8)
Angry faces	-5.6 (1.8)	-4.3 (2.5)	5.4 (3.0)	4.9 (2.1)
Surprised faces	0.1 (1.4)	-0.3 (1.7)	4.2 (3.2)	4.1 (2.7)
Afraid faces	-2.5 (2.4)	-3.9 (2.6)	2.0 (3.8)	4.4 (1.8)
Sad faces	-4.0 (3.0)	-1.8 (1.9)	0.3 (3.8)	0.4 (2.5)

Note. *n* = 22 (Male: 12; Female: 10)
Mean (Standard deviation)
Valance: 'very pleasant', 5; 'very unpleasant' -5
Arousal: 'very aroused' 5; 'very relaxed' -5

5.4 Discussion

In this chapter, I investigated whether there are gender differences in N170 and LPP elicited by discriminating emotional facial expressions (happy, angry, surprised, afraid, and sad) from emotionally neutral faces, even when empathy trait does not differ between genders.

Overall results indicated that N170 did not show any gender difference, whereas LPP was greater in females than in males (Table 5.2). This suggests that gender differences in face processing may be clearer in the late stage (reflected in LPP) than in the early stage (reflected in N170) of attention, supporting previous findings (Wang et al., 2011; Han et al., 2008). In the study by Wang et al. (2011), participants discriminated the familiarity of faces (faces of family members vs. strangers), showing a gender difference in LPP (defined as P3 in the study), but not in N170. The study results indicated that males showed greater LPP in response to their own faces than to the faces of their parents, whereas females did not (Wang et al., 2011). In addition, in the study by Han et al. (2008), participants watched pictures of hands in neutral and painful situations (e.g., hands trapped in a door) and a gender difference was shown only in the late ERP component (340-540 ms), not in the early ERP component (140-320 ms). Females showed greater LPP (defined as P3 in that study) in response to picture of hands in painful situations than in neutral situations, whereas males did not (Han et al., 2008). Taken together, the results suggest a tendency for gender differences to become clearer in the late stage of attention than in the early stage of attention in the processing of human figures, including human faces and hands.

Gender difference in N170

Although the averaged ERP waveform showed a more negative N170 in females than in males (Fig. 5.2), the current study failed to find any significant gender difference in N170.

This suggests that no gender difference in N170 is elicited by face processing, supporting previous results of no gender difference in N170 elicited when judging whether a stimulus is a face or not (Batty & Taylor, 2003) or whether a face is familiar or not (Wang et al., 2011). However, as mentioned in the Introduction, Sun et al. (2010) reported that only females showed a more negative N170 when discriminating orientations (right or left) of faces compared to genders of faces. I thus still cannot exclude the possibility that task demand might affect gender differences in N170, as suggested by Sun et al. (2010).

In addition, the current result indicated that both males and females showed a more negative N170 in the right posterior temporal area (T6) than in the left posterior temporal area (T5). As N170 has been reported to be more negative in the right hemisphere than in the left hemisphere in many studies (e.g., Bentin et al., 1996; Campanella et al., 2000; Taylor et al., 1999), the current result seems to reconfirm previous findings. However, one previous study (Proverbio et al., 2006) reported a gender difference in the hemispheric asymmetry of N170. In that study (Proverbio et al., 2006), participants discriminated facial expressions (neutral or distressed) of infants and the results indicated that males showed right hemispheric dominance of N170, whereas females did not. On the other hand, other studies relating to gender difference in N170 mentioned above (Sun et al., 2010; Wang et al., 2011; Batty & Taylor, 2003) did not report any hemispheric asymmetry of N170. Concluding whether or not gender differences exist in the hemispheric asymmetry of N170 is therefore difficult.

Taken together, the current result for N170 indicated that no gender difference exists in the very early (about 170 ms after face onset) stage of face processing, at least in the task to discriminate emotional facial expressions (happy, angry, surprised, afraid, and sad) from neutral faces. However, some questions remain as to whether gender differences in N170 might be affected by task demand and whether hemispheric asymmetry exists for N170. Future research is thus needed to address these questions.

Gender difference in LPP

In contrast to N170, gender differences were seen in LPP, with females showing more positive LPP peak amplitude in response to faces than males (Table 5.2). This result reconfirmed previous results that LPP amplitude elicited in response to faces is greater in females than in males (Guillem & Mograss, 2005; Orozco & Ehler, 1998; Proverbio et al., 2009).

As shown in the Chapter 2 and Chapter 4, in response to human faces, LPP amplitude is affected by the empathy trait of individuals. However, as mentioned in Chapter 3, the previous studies have not considered the empathy trait of male and female participants when investigating gender differences in the LPP response elicited by human faces. Whether the greater LPP amplitude elicited by faces in females than in males was because of empathy trait or gender *per se* had thus remained unclear. The present results suggest that females pay attention to human faces more than males in the late stage of face processing, even when no gender difference in empathy trait is present (Table 5.1), supporting result of Chapter 3.

On the other hand, a difference was seen between the present and previous studies in facial expression that showed gender difference in LPP. In the present study, compared with males, females showed greater LPP peak amplitude in response to angry, surprised, and sad faces, but not in response to happy or afraid faces (Table 5.2). However, in the previous study by Orozco & Ehlers (1998) in which participants discriminated happy and sad faces from emotionally neutral faces under an oddball paradigm, females showed greater LPP (defined as P450 in that study) amplitude in response to both sad faces and happy faces. In other words, although the present study adopted a similar oddball task to the previous study (Orozco & Ehler, 1998) to discriminate emotional faces from neutral faces, I failed to find any significant gender difference in LPP amplitude to happy faces, contrasting with the previous study (Orozco & Ehler, 1998).

This difference between present and previous results (Orozco & Ehler, 1998) might be also explained by the lack of gender differences in empathy trait in the present study (Table 5.1). In concrete terms, when males and females show the same level of empathy trait, gender differences in late-stage attention (reflected in LPP) might disappear in responses to faces related to pleasant emotions (e.g., happy faces), but not in response to faces related to unpleasant emotions (e.g., sad faces). This might be related to biological specialization between males and females, as mentioned in Chapter 3. In terms of survival, noticing an unpleasant emotional state in others has been considered more important than noticing a pleasant emotional state in others for both males and females. However, this effect might be clearer in females than in males, because females have less physical attributes (size, strength, and speed) compared with males (Wood & Eagly, 2002). Female reproductive capacity also might be related to this effect, as females traditionally have played a social role of raising children through gauging emotional states of infants from their faces (Wood & Eagly, 2002). However, I could not identify any gender difference in LPP amplitude for afraid faces, although this facial expression is also associated with negative emotions. The interpretations mentioned above thus appear to be of limited use.

Limitations

The limitations of this chapter are as follows: first, as in Chapter 3, I could not analyze ERP responses elicited by male and female faces separately, due to the limited average number of trials. Second, as in Chapter 3, I found a gender difference only in LPP peak amplitude, not in mean amplitude (i.e., averaging amplitude in specific temporal windows; defined as early LPP and late LPP in the present study). Although both peak and mean amplitude have been used in ERP studies, some authors (e.g., Luck, 2005) have argued that peak amplitude is a less credible index than mean amplitude. The gender difference in LPP shown in the present study might thus be considered weak.

Conclusion

I found gender differences in discriminating facial expressions in LPP, but not in N170. This suggests that gender differences in face processing are more obvious in the late stage (reflected in LPP, 300-800 ms after face onset) than in the early stage (reflected in N170, about 170 ms after face onset) of attention, in line with previous studies. In addition, females may pay attention to human faces more than males in the late stage of face processing, even when no gender difference in empathy trait is present. This might be related to biological specialization between genders, such as physical attributes and reproductive capacity.

Chapter 6
Conclusion

6.1 Summary and general discussion

This thesis aimed to investigate effect of empathy trait and gender on attention to faces. Empathy trait was measured by using Interpersonal Reactivity Index (IRI) questionnaire (Davis, 1980). Even-related potential (ERP) was recorded during discrimination of facial expressions. N170 and late positive potential (LPP) components of ERP were analyzed for attention as indices of early and late stage of attention, respectively.

Relationship between empathy trait and attention to faces

In Chapter 2 and Chapter 4, the relationship between empathy trait and attention response to faces was investigated. The results of Chapter 2 indicated that IRI score correlated positively with LPP elicited when discriminating facial expressions (happy or angry), but not flower colors (yellow or purple). This suggests that individuals with high empathy trait thus might have a tendency to be especially sensitive to face, not to non-face stimuli.

The results of Chapter 4 indicated that IRI score correlated negatively with N170 in response to happy, angry, surprised, and afraid faces, but correlated positively with LPP in response to happy, angry, surprised, afraid, and sad faces. This suggests that individuals with high empathy pay greater attention to various facial expressions than those with low empathy, from the very early stage (reflected in N170) to the late stage (reflected in LPP) of facial processing.

This consistent result between Chapter 2 and Chapter 4 strongly suggests that empathy trait is an important factor of individual difference in attention to faces, supporting previous studies (Jabbi et al., 2007; Singer et al., 2004; Hooker et al., 2008; Krämer et al., 2010; Chakrabarti et al., 2006; Soria Bauser et al., 2012; Choi & Watanuki, 2012). Increased attention to faces in individuals with high empathy suggests that understanding emotional state of others is more important for individuals with high empathy than for those with low empathy. This might be because individuals with high empathy try to behave appropriately in social situations more than those with low empathy. This interpretation indicates that ability and methods to adapt to social environments differ depending on the empathy trait of individuals.

Gender difference in attention to faces

In Chapter 3 and Chapter 5, gender difference in attention response to faces was investigated. The results of chapter 3 indicated that females, compared with males, showed greater LPP difference between when discriminating facial expressions and when discriminating flower colors. This suggests that females are especially sensitive to human faces.

The results of Chapter 5 indicated that there were gender differences in discriminating facial expressions in LPP, but not in N170. This suggests that gender differences in face processing are more obvious in the late stage (reflected in LPP) than in the early stage (reflected in N170) of attention.

These results from Chapter 3 and Chapter 5 suggest that there are gender differences in attention response to faces, reconfirming previous studies (Lee et al., 2002; Schulte-Rüther et al., 2008; Spreckelmeyer, 2009; Campanella et al., 2004; Gullim & Mugrass, 2005; Orozco & Ehlers, 1998; Proverbio et al., 2009; Sun et al., 2010; Wang et al., 2011). Increased attention to faces in females suggests that understanding emotional state of others is more important for females than for males. Moreover, it is suggested that gender difference in attention responses to faces might be because of gender *per se* more than empathy trait of individuals, as no gender difference in empathy trait is present in Chapter 3 and Chapter 5. This interpretation indicates that increased attention to face in females is related with biological specialization between genders, such as reproductive capacity of females.

Conclusion

It is important for humans to pay attention to the faces of other humans and to discriminate facial expressions accurately. However, attention response to faces differs depending on characteristics of individuals. In this thesis, I focused on empathy trait and gender as factors of individual difference in attention response to faces. The results of two experiments showed increased attention to face in individuals with high empathy compared with those with low empathy, and in females compared with in males. This is interpreted as that empathy trait and gender of observer affect importance of understanding emotional state of others. Taken together, this thesis suggests that ability and methods to adapt to social environments differ depending on both empathy trait of individuals and biological characteristics of gender.

6.2 Future work

In recent review of neuroscience of empathy (Singer & Lamm, 2009), authors mentioned that some questions should be focused in future research in empathy. Among the questions, the one question is how empathy is related with prosocial behavior. Singer and Lamm (2009) suggested that sharing others' feeling makes people understand mental states and actions of others better and thus empathy possibly promotes prosocial behaviors. This idea is supported by the present results of this thesis that individuals with high empathy trait pay attention more than those with low empathy trait when discriminating facial expressions.

Moreover, Fishman et al. (2011) showed that LPP (defined as P300 in that study) response to images of human faces is greater in extroverts than introverts. Extroversion is a concept that includes vigorous accessibility and aggressiveness towards society (John & Srivastava, 1999), and is a personality trait strongly linked to prosocial behavior. Studies using questionnaires have shown different results on the relationship between empathy and extroversion (de Corte et al., 2007; Jolliffe & Fassington, 2006), and this relationship has yet to be clarified. Nonetheless, this thesis and the results of Fishman et al. (2011), which examined levels of empathy and extroversion, respectively, both showed relationships with increases in LPP response to human faces, i.e., increased importance of faces as stimuli, suggesting the possibility that level of empathy is associated with extroversion, and ultimately with prosocial behavior.

However, in order to clarify the relationship between empathy and prosocial behaviors, more future researches are needed. In both the present study and the previous study (Fishman et al., 2011), participants discriminated facial expressions or genders. These tasks are thought to be a bit simple for examining prosocial behaviors. Thus, future studies should adopt tasks to involve participants with more complicated social situations, compared with task to discriminate facial expressions or genders, in order to clarify the relationship between empathy and prosocial behaviors.

References

Amrhein C, Mühlberger A, Pauli P, Wiedemann G: **Modulation of event-related brain potentials during affective picture processing: a complement to startle reflex and skin conductance response?** *Int J Psychophysiol* 2004, **54:**231–240.

Ally BA, McKeever JD, Waring JD, Budson AE: **Preserved frontal memorial processing for pictures in patients with mild cognitive impairment.** *Neuropsychologia* 2009, **47:**2044–2055.

Batty M, Taylor MJ: **Early processing of the six basic facial emotional expressions.** Brain Res *Cogn Brain Res* 2003, **17:**613–20.

Baron-Cohen S., Richler J, Bisarya D, Gurunathan N, Wheelwright S. **The systemizing quotient: an investigation of adults with Asperger syndrome or high-functioning autism, and normal sex differences.** *Philosophical Transactions of the Royal Society* 2003, **358:**361–374.

Baron-Cohen S, Wheelwright S: **The Empathy Quotient (EQ). An investigation of adults with Asperger syndrome or high functioning autism, and normal sex differences.** *J Autism Dev Disord* 2004, **34:**163–175.

Bentin S, Allison T, Puce A, Perez E, McCarthy G: **Electrophysiological studies of face perception in humans.** *J Cogn Neurosci* 1996, **8:**551–565.

Bressler SL: **Event-Related Potentials.** In *The Handbook of Brain Theory and Neural Networks*. Edited by Arbib MA. MIT Press, Cambridge MA; 2002:412–415.

Campanella S, Hanoteau C, Dépy D, Rossion B, Bruyer R, Crommelinck M, Guérit JM: **Right N170 modulation in a face discrimination task: an account for categorical perception of familiar faces.** *Psychophysiology* 2000, **37:**796–806.

Campanella S, Rossignol M, Mejias S, Joassin F, Maurage P, Debatisse D, Bruyer R, Crommelinck M, Guérit JM: **Human gender differences in an emotional visual oddball task: an event-related potentials study.** *Neurosci Lett* 2004, **367:** 14–18.

Carr L, Iacoboni M, Dubeau MC, Mazziotta JC, Lenzi GL: **Neural mechanisms of empathy in humans: a relay from neural systems for imitation to limbic areas.** *Proc Natl Acad Sci U S A* 2003, **29:**5497–5502.

Chakrabarti B, Bullmore E, **Baron-Cohen S: Empathizing with basic emotions: common and discrete neural substrates.** *Soc Neurosci* 2006, **1:**364–384.

Choi D, Watanuki S: **Physiological recovery responses to socially pleasant images in stress**. *Jpn J Physiol Anthropol* 2012, 17:167–173. in Japanese with English abstract.

Cuthbert BN, Schupp HT, Bradley MM, Birbaumer N, Lang PJ: **Brain potentials in affective picture processing: covariation with autonomic arousal and affective report.** *Biol Psychol* 2000, **52:**95–111.

Davis MH: **Measuring individual differences in empathy: evidence for a multidimensional approach.** *J Pers Soc Psychol* 1983, **44:**113–126.

Davis MH: **Empathy: A social psychological approach.** Boulder, CO: Westview Press; 1995.

Decety J, Jackson PL: **The functional architecture of human empathy.** *Behav Cogn Neurosci Rev* 2004, **3:**71–100.

de Corte K, Buysse A, Verhofstadt LL, Roeyers H, Ponnet K, Davis MH: **Measuring empathic tendencies: Reliability and validity of the Dutch Version of the Interpersonal Reactivity Index.** *Psychologica Belgica* 2007, **44:** 235–260.

Eimer M, Holmes A: **An ERP study on the time course of emotional face processing.** *Neuroreport* 2002, **13:**427–431.

Eimer M, Holmes A, McGlone FP: **The role of spatial attention in the processing of facial expression: an ERP study of rapid brain responses to six basic emotions.** *Cogn Affect Behav Neurosci* 2003, **3:**97–110.

Ekman P, Friesen WV: **Constants across cultures in the face and emotion.** *J Pers Soc Psychol* 1971, **17:**124–129.

Fishman I, Ng R, Bellugi U: **Do extraverts process social stimuli differently from introverts?***CognNeurosci* 2011, **2:**67–73.

Foti D, Hajcak G, Dien J: **Differentiating neural responses to emotional pictures: evidence from temporal-spatial PCA.***Psychophysiology* 2009, **46:**521–530.

Gazzaniga M: *Human: The Science Behind What Makes us Unique*. New York: HarperCollins Publisher; 2008.

Guillem F, Mograss M: **Gender differences in memory processing: evidence from event-related potentials to faces.** *Brain Cogn* 2005, **57:** 84–92.

Han S, Fan Y, Mao L: **Gender difference in empathy for pain: an electrophysiological investigation.** *Brain Res* 2008, **1196:**85–93.

Hajcak G, MacNamara A, Olvet DM: **Event-related potentials, emotion, and emotion regulation: an integrative review.** *Dev Neuropsychol* 2010, **35:**129–155.

Hajcak G, Weinberg A, MacNamara A, Foti D: **ERPs and the study of emotion**. In *Oxford Handbook of Event-related Potential Components*. Edited by Luck SJ, Kappenman ES. New York: Oxford University Press; 2012:441–474.

Hauswald A, Schulz H, Iordanov T, Kissler J: **ERP dynamics underlying successful directed forgetting of neutral but not negative pictures.** *Soc Cogn Affect Neurosci* 2011, **6:**450–459.

Herrmann MJ, Aranda D, Ellgring H, Mueller TJ, Strik WK, Heidrich A, Fallgatter AJ: **Face-specific event-related potential in humans is independent from facial expression.** *Int J Psychophysiol* 2002, **45:**241–244.

Herrmann CS, Knight RT: **Mechanisms of human attention: event-related potentials and oscillations.** *Neuroscience & Biobehavioral Reviews* 2001, **25:** 465-476.

Holmes A, Vuilleumier P, Eimer M: **The processing of emotional facial expression is gated by spatial attention: evidence from event-related brain potentials.** *Brain Res Cogn Brain Res* 2003, **16:**174–184.

Hooker CI, Verosky SC, Germine LT, Knight RT, D'Esposito M: **Mentalizing about emotion and its relationship to empathy.** *Soc Cogn Affect Neurosci* 2008, **3:**204–217.

Jabbi M, Swart M, Keysers C: **Empathy for positive and negative emotions in the gustatory cortex.** *Neuroimage* 2007, **34:**1744–1753.

John OP, Srivastava S: **The Big Five trait taxonomy: History, measurement, and theoretical perspectives.** *Handbook of personality: Theory and research*. Edited by Pervin LA, John OP. New York: Guilford; 1999:102-138.

Johnson VS, Wang XT: **The Relationship between Menstrual Phase and the P3 Component of ERPs.** *Psychophysiology* 1991, **28:**400–409.

Jolliffe D, Farrington DP: **Development and validation of the Basic Empathy Scale.** *Journal of Adolescence* 2006, 29:589–611.

Kim H, Somerville LH, Johnstone T, Alexander A, Whalen PJ: **Inverse amygdala and medial prefrontal cortex responses to surprised faces.** *Neuroreport* 2003, **14:**2317–2322.

Krämer UM, Mohammadi B, Doñamayor N, Samii A, Münte TF: **Emotional and cognitive aspects of empathy and their relation to social cognition - an fMRI-study.** *Brain Res* 2010, **1311:**110–120.

Kujawa A, Weinberg A, Hajcak G, Klein DN: **Differentiating event-related potential components sensitive to emotion in middle childhood: Evidence from temporal-spatial PCA.***Dev Psychobiol* 2012, **55:**539–550.

Lee T, Liu HL, Hoosain R, Liao WT, Wu CT, Yuen KS, Chan CC, Fox PT, Gao JH: **Gender differences in neural correlates of recognition of happy and sad faces in humans assessed by functional magnetic resonance imaging.** *Neuroscience letters* 2002, **333:**13–16.

Leutgeb V, Schäfer A, Köchel A, Schienle A: **Exposure therapy leads to enhanced late frontal positivity in 8- to 13-year-old spider phobic girls.** *Biol Psychol* 2012, **90:**97–104.

Leslie KR, Johnson-Frey SH, Grafton ST: **Functional imaging of face and hand imitation: towards a motor theory of empathy.** *Neuroimage* 2004, **21:**601–607.

Lang P, Bradley MM, Cuthbert BN: **Motivated attention: Affect, activation, and action**. In *Attention and Orienting: Sensory and Motivational Processes.* Edited by Lang PJ, Simons RF, Balaban MT. Hillsdale, NJ: Erlbaum; 1997:97–136.

Luck SJ: **Ten simple rules for designing ERP experiments.** In *Event-related potentials: A methods handbook*, Edited by Handy TC. MIT Press; 2005: 17–32.

Lundqvist D, Flykt A, Ohman A: *The Karolinska Directed Emotional Faces - KDEF(CD ROM)*: Department of Clinical Neuroscience, Psychology Section, KarolinskaInstitutet, Stockholm; 2011.

Luo W, Feng W, He W, Wang NY, Luo YJ: **Three stages of facial expression processing: ERP study with rapid serial visual presentation.** *Neuroimage* 2010, **49:**1857–1867.

McClure EB: **A meta-analytic review of sex differences in facial expression processing and their development in infants, children, and adolescents.** *Psychol*. *Bull* 2000, 126:424–453.

Mehrabian A, Epstein N: **A measure of emotional empathy.** *Journal of Personality* 1972, **40:**525–543.

Neta M, Norris CJ, Whalen PJ: **Corrugator muscle responses are associated with individual differences in positivity-negativity bias.** *Emotion* 2009, **9:**640–648.

Neta M, Davis FC, Whalen PJ: **Valence resolution of ambiguous facial expressions using an emotional oddball task.** *Emotion* 2011, **11:**1425–1433.

O’Doherty J: **Reward representations and reward-related learning in the human brain: Insights from neuroimaging.** *Current Opinion in Neurobiology* 2004, **14:**796–776.

Olofsson JK, Nordin S, Sequeira H, Polich J: **Affective picture processing: an integrative review of ERP findings.** *Biol Psychol* 2008, **77:**247–265.

Orozco S, Ehlers CL: **Gender differences in electrophysiological responses to facial stimuli.** *Biol Psychiatry* 1998, **44:** 281–289.

Proverbio AM, Brignone V, Matarazzo S, Del Zotto M, Zani A: **Gender differences in hemispheric asymmetry for face processing.** *BMC Neurosci* 2006, **7:**44.

Proverbio AM, Adorni R, Zani A, Trestianu L: **Sex differences in the brain response to affective scenes with or without humans.** *Neuropsychologia* 2009, **47:**2374–2388.

Sakurai S: **The relationship between empathy and helping behavior in college students.** *Bulletin* 1998, **37:**149–154 (in Japanese with English abstract).

Schulte-Rüther M, Markowitsch HJ, Fink GR, Piefke M: **Mirror neuron and theory of mind mechanisms involved in face-to-face interactions: a functional magnetic resonance imaging approach to empathy.** *J Cogn Neurosci* 2007, **19:**1354–1372.

Schulte-Rüther M, Markowitsch HJ, Shah NJ, Fink GR, Piefke M: **Gender differences in brain networks supporting empathy.** *Neuroimage* 2008, **42:** 393–403.

Schupp HT, Cuthbert BN, Bradeley MM, Cacioppo JT, Ito T, Lang PJ: **Affective picture processing: the late positive potential is modulated by motivational relevance.** *Psychophysiology* 2000, **37:**257–261.

Schupp HT, Flaisch T, Stockburger J, Junghöfer M: **Emotion and attention: event-related brain potential studies.** *Progress in brain research* 2006, **156:**31-51.

Simons R, Detenber B, Cuthbert B, Schwartz D, Reiss J. **Attention to television: Alpha power and its relationship to image motion and emotional content.** *Media Psychology* 2003, **5:** 283–301.

Singer T, Seymour B, O'Doherty J, Kaube H, Dolan RJ, Frith CD: **Empathy for pain involves the affective but not the sensory components of pain.** *Science* 2004, **303:**1157–1161.

Singer T, Lamm C. **The Social Neuroscience of Empathy.** *The Year in Cognitive Neuroscience 2009: Ann. N.Y. Acad. Sci* 2009, **1156:** 81–96.

Smith A: **Cognitive empathy and emotional empathy in human behavior and evolution.** Psychological Record 2006, 56:3–21.

Soria Bauser D, Thoma P, Suchan B: **Turn to me: electrophysiological correlates of frontal vs. averted view face and body processing are associated with trait empathy.** *Front Integr Neurosci* 2012, **6:**106.

Spreckelmeyer KN, Kutas M, Urbach TP, Altenmüller E, Münte TF: **Combined perception of emotion in pictures and musical sounds.** *Brain Res* 2006, **1070:**160–170.

Sun Y, Gao X, Han S: **Sex differences in face gender recognition: an event-related potential study.** *Brain res* 2010, **1327:**69-76.

Taylor MJ, McCarthy G, Saliba E, Degiovanni E: **ERP evidence of developmental changes in processing of faces.** *Clin Neurophysiol* 1999, **110:**910–915.

Tepas D, Price J: **What is stress and what is fatigue?** In *Stress, workload, and fatigue.* Edited by Hancock P, Desmond P. Mahwah: Earlbaum, 2001: 607-622.

Towle VL, Bolaños J, Suarez D, Tan K, Grzeszczuk R, Levin DN, Cakmur R, Frank SA, Spire JP: **The spatial location of EEG electrodes: locating the best-fitting sphere relative to cortical anatomy.** *Electroencephalogr Clin Neurophysiol* 1993, **86:**1–6.

Vogeley K, Fink GR: **Neural correlates of the first-personperspective.** *Trends Cogn Sci* 2003, **7:**38–42.

Wang J, Kitayama S, Han S: **Sex difference in the processing of task-relevant and task-irrelevant social information: an event-related potential study of familiar face recognition.** *Brain Res* 2011, **1408:**41–51.

Weinberg A, Ferri J, Hajcak G: **Interactions between attention and emotion: insights from the late positive potential**. In *Handbook of Cognition and Emotion.* Edited by Robinson MD, Watkins ER, Harmon-Jones E. New York: Guilford Press; 2013:35–54.

Weinberg A, Hilgard J, Bartholow BD, Hajcak G: **Emotional targets: evaluative categorization as a function of context and content.** *Int J Psychophysiol* 2012, **84:**149–154.

Weinberg A, Hajcak G: **The late positive potential predicts subsequent interference with target processing.** *J Cogn Neurosci* 2011, **23:**2994–3007.

Wood W, Eagly AH: **A cross-cultural analysis of the behavior of women and men: implications for the origins of sex differences.** *Psychol Bull* 2002, **128:** 699–727.

Zaki J, Ochsner KN: **The neuroscience of empathy: progress, pitfalls and promise.** *Nat Neurosci* 2012, **15:**675–680.

Zhang D, Luo W, Luo Y: **Single-trial ERP analysis reveals facial expression category in a three-stage scheme.** *Brain Res* 2013, **1512:**78–88.

Abbreviations

ANOVA, Analysis of variance
BEES, Balanced Emotional Empathy Scale
EEG, Electroencephalography
EOG, Electrooculography
ERP, Event-related potential
EQ-SQ, Empathy- and Systemizing quotient
fMRI, functional magnetic resonance imaging
IRI, Interpersonal reactivity index
LPP, Late positive potential
SD, Standard deviation

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