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RESEARCH ARTICLE

Responses to affective pictures depicting humans: late positive potential reveals a sex-related effect in processing that is not present in subjective ratings

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Abstract We examined sex-related effects in the amplitudes of the late positive potential (LPP), an event-related potential elicited by the presentation of emotional stimuli. Sixteen females and 18 males viewed emotional pictures to perform a visual detection task. In female participants, viewing unpleasant pictures elicited larger LPP (550–900 ms) when the pictures contained humans (human pictures) than when they did not contain humans (non-human pictures). For male participants, the results were reversed, with smaller LPP for unpleasant human pictures. Subjective ratings of valence in both female and male participants showed that unpleasant human pictures were evaluated less negatively than unpleasant non-human pictures. The results indicate that greater LPP amplitude for human than for non-human pictures occurred in females irrespective of subjective evaluations. This suggests that relatively robust processes in females cause sex-related effects in sensitivity to human pictures.

Keywords Event-related potential (ERP) · Late positive potential (LPP) · Emotion · Sex-related effects · Affective picture

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Introduction

A number of studies investigating electrophysiological responses to emotional stimuli have proposed that the late positive potential (LPP) of event-related potentials (ERPs) is one of the prominent components that reflect emotional responses (Olofsson et al. 2008, for a review). The LPP, which has a parietal maximum scalp distribution with an onset latency of about 300 ms (Ito et al. 1998), is associated with perceptual processing, affective evaluation, and motivated attention to emotional stimuli (Schupp et al. 2000). Viewing emotional (pleasant and unpleasant) pictures elicits greater LPP amplitudes than viewing neutral pictures. It has also been proposed that viewing unpleasant pictures may result in greater LPP amplitude than viewing pleasant pictures (Huang and Luo 2006; Schupp et al. 2004). Furthermore, it is known that the arousal level of pictures, as well as the valence level, can influence the amplitude of LPP. Weinberg and Hajcak (2010) demonstrated that the amplitude of LPP was greater when participants viewed high-arousal pictures than when they viewed low-arousal pictures, implying that the LPP reflects attention to emotional content (Hajcak et al. 2011). Task requirements also affect the amplitude of LPP. Wiens et al. (2011) demonstrated that the LPP amplitude was larger when participants were required to respond to target pictures that had been memorized than when they responded to a target letter superimposed on the pictures. Taken together, this evidence suggests that the LPP reflects perceptual, emotional, and attentional processing of affective pictures, and its amplitude can be modulated by task requirements.

It has been proposed that cognitive processes in response to emotional stimuli differ in some ways for females and males (see Kret and De Gelder 2012, for a review), and the sex-related effects in emotional responses may be greater when the pictures contain people (human pictures) than when they do not depict people (non-human pictures; see Christov-Moore et al. 2014, for a review). Electrophysiological research has shown that amplitudes of the LPP elicited by viewing emotional pictures were larger when the pictures depicted humans than when they depicted non-humans, and this trend was more pronounced in females than in males (Althaus et al. 2014; Groen et al. 2013; Proverbio et al. 2009). For example, Proverbio et al. (2009) examined the amplitudes of LPP elicited by viewing four categories of emotional pictures: valence (pleasant vs. unpleasant) × content (human vs. non-human). The LPP amplitudes were larger for human pictures than for non-human pictures, and, more importantly, the amplitudes when viewing negative human pictures were 1.6× larger in females than in males.

Although there is empirical evidence that the amplitude of LPP elicited by viewing human pictures is greater in females than in males, it is still unclear whether or not such sex-related effects can actually be attributed to the presence of humans in the pictures. In previous studies (Althaus et al. 2014; Groen et al. 2013; Proverbio et al. 2009), the valence of unpleasant human pictures was rated lower than that of unpleasant non-human pictures by both females and males (more than 1.3 SD lower for human than for non-human pictures). This may have occurred because some of the unpleasant human pictures included mutilated bodies, which have great negative impact on observers. Furthermore, females have the tendency to rate unpleasant human pictures with lower scores than do males. In fact, mean evaluation scores of the unpleasant human pictures used in previous studies were .78 SD or more lower in females than in males. Similarly, the pleasant human pictures used in previous studies were rated higher in valence and arousal than the pleasant non-human pictures, and this tendency was stronger in females than males. Therefore, it is possible that the greater amplitude of LPP elicited in females by viewing human pictures is due to the greater negative (or positive) impact of the pictures, irrespective of the presence of humans. In this case, the sex-related effects cannot be attributed to sensitivity to humans. Before accepting the notion that this sex-related effect is caused by sensitivity to humans, it is necessary to examine whether or not the sex-related effect in the amplitude of LPP elicited by human pictures can be observed irrespective of the subjective evaluation of the pictures. In other words, if females' greater sensitivity to humans results in a sex-related effect on LPP for human pictures, this effect should remain even when the valence and arousal levels of human and non-human pictures are equivalent.

In the present study, we examined sex-related effects in LPP amplitudes that were elicited by human and non-human emotional pictures. To this end, we used emotional pictures from the International Affective Picture System (IAPS, Lang et al. 2008), in six categories: three valence levels (pleasant, neutral, and unpleasant) × two types (human and non-human). Mutilation pictures and erotic pictures were not used in the present study, because mutilation pictures have great negative impact and result in extremely high arousal, and erotic pictures create greater arousal in males than in females (Sabatinelli et al. 2004). As noted above, it has been reported that the LPP reflects attention as well as emotional responses. To examine the effects of attention, participants performed two different tasks: an object task and an orientation task. In the object task, participants had to look for a train in each picture, which required them to recognize the context of the scene. In the orientation task, participants had to detect a slight rotation of each picture, which required them to attend to the physical properties (i.e., slant of edges) of the stimulus rather than the detailed context of the picture. As Wiens et al. (2011) demonstrated, when the task requires attention to the content of emotional pictures, affective processing is facilitated, resulting in greater LPP amplitude. If the sex-related effect for human pictures depends on attentive processing of the content of the pictures, the effect could be larger in the object task than in the orientation task. On the other hand, if the sex-related effect appears irrespective of attention to pictures, the magnitude of the effect should be equivalent between task conditions.

After performing the object and orientation tasks, participants evaluated the valence and arousal of all of the IAPS pictures presented in the experiment. If females are more sensitive to humans than males and LPP reflects such effects, females should show greater LPP amplitudes while viewing human pictures relative to non-human pictures, even when the human pictures do not have great emotional impact (i.e., with mutilation and erotic pictures excluded from the picture set). Furthermore, if the sex-related effect for human pictures depends on attentive processing of the contents of pictures, this effect should be greater in the object task than in the orientation task.

Method

Participants

Sixteen young females (18–28 years old) and 20 young males (19–35 years old) participated. All participants had normal or corrected-to-normal vision. They received payment (1250 yen/1 h) at the end of all experimentation. The study was approved by the National Institute of Advanced Industrial Science and Technology (AIST) Safety and Ethics committee and was conducted only after each of the participants had given written informed consent.

Apparatus and stimuli

The visual stimuli were presented on a 17 in. cathode ray tube (CRT) display (Sony, Trinitron Multiscan G220) with the resolution of 1280 × 1024 pixels, which was controlled by a computer operating Mac OSX, MATLAB (MathWorks Inc.), and Psychophysics Toolbox (Brainard 1997; Pelli 1997; Kleiner et al. 2007). The refresh rate of the display was set to 60 Hz, and the viewing distance was approximately 60 cm.

Five hundred seventy-six color photographs, each with a width of 1024 pixels and a height of 768 pixels (approximately 25.0° × 17.6°), were used as visual stimuli. Three hundred eighty-four of the 576 pictures were taken from the IAPS. The picture set included photographs of animals, babies, children, crime scenes, emotional faces, families, furniture, flowers, food, garbage, inorganic substances, insects, landscapes, plants, ruins, vehicles, weapons, and so on (see "Appendix" section for details). Half depicted humans (human, 192 pictures) and the other half did not include humans (non-human, 192 pictures). The pictures were classified into three valence categories: pleasant, neutral, and unpleasant, based on the scores of Lang et al. (2008), such that there were 64 pictures for each valence × human/non-human category (see Table 1). Figure 1 shows the average valence score of each picture category. The remaining 192 pictures, which were chosen from copyright-free databases, were used as target stimuli. All target stimuli were emotionally "neutral" (pleasant and unpleasant pictures were not included). Half of the target stimuli depicted humans, and the other half did not include humans.

Table 1 Numbers and type, content, and valence of pictures used as nontarget (384 total) and target (192 total) stimuli

Type	Content	Valence	Object task	Orientation task
IAPS (non-target)	Human	Pleasant	64	
		Neutral	64	
		Unpleasant	64	
	Non-human	Pleasant	64	
		Neutral	64	
		Unpleasant	64	
Target	Human	Neutral	48	48
	Non-human	Neutral	48	48

Procedure

Each participant performed two tasks: an object task and an orientation task. In the object task, participants were required to press a button as quickly and accurately as

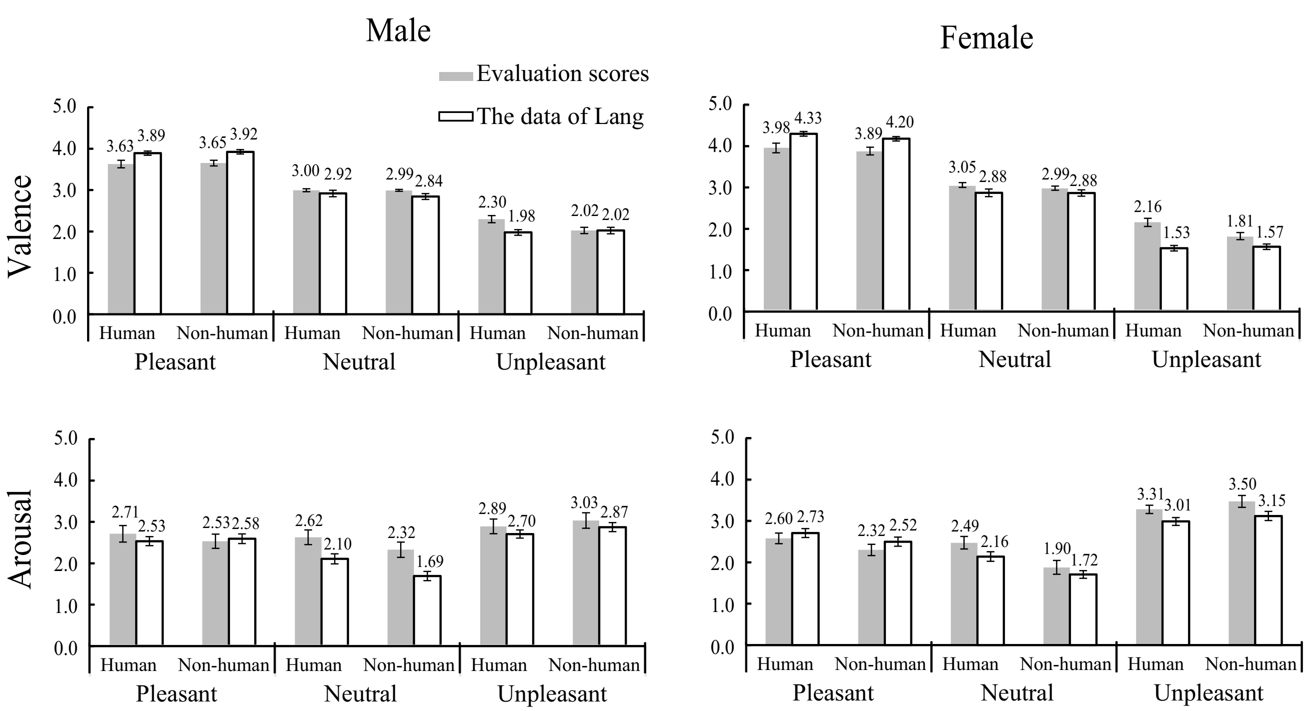

Fig. 1 Mean valence and arousal scores for IAPS, representing variability of ratings of the same pictures across the present study and Lang et al. (2008). *Gray bars* represent evaluation scores of the present study. *White bars* represent evaluation scores computed from the data of Lang et al. (2008). *Error bars* indicate one standard error (color figure online)

possible using their right index finger when they detected a train in a picture, that is, a go/no-go task. In the orientation task, target stimuli were presented in a slightly rotated manner (with a counterclockwise rotation of 5°), and participants were required to press a button as quickly and accurately as possible when they detected a target. That is, the object task required the participant to recognize the context of a scene, whereas the orientation task did not require detailed analysis of the context. To eliminate effects related to task order, the order of the object and orientation tasks was counterbalanced across participants.

In both the object and orientation tasks, the same IAPS stimuli (384 pictures) were used as nontarget pictures, in order to prevent effects of physical and psychological stimulus differences on ERPs. Because the target in the object task was defined as the presence of a train, none of the nontarget IAPS pictures included a train. For the target stimuli that were not used in the examination of ERPs, we chose different pictures for each task: 96 for the object task (stopped train: 38 images with human and 12 without; running trains: 10 images with humans and 36 without; no pictures of train interiors) and 96 for the orientation task (outdoor scenes: 35 images with humans and 40 without; indoor scenes: 13 images with humans and 8 without). Examples of target pictures are shown in Fig. 2a.

A schematic illustration of the experimental procedure is shown in Fig. 2b. Each trial began with the presentation of a black fixation cross (5.0° × 5.0°) for 1000 ms at the center of display on a gray background, followed by the presentation of a picture for 2000 ms. The next trial began immediately after the offset of the picture. Each participant performed 8 blocks for each task, with each block consisting of 60 trials (480 trials for each task). In each block, a target appeared in 20 % of the trials; the pictures were otherwise presented in random order. A practice block was given prior to each task (60 trials for each task). All pictures used in the practice blocks were different from those in the experimental blocks. No feedback was given in the practice block. Participants were given a brief rest after each block.

After performing these tasks, participants were required to evaluate the valence and arousal of each of the IAPS pictures while viewing each picture using the self-assessment manikin (SAM) (Bradley and Lang 1994); with valence rated 1 (*unpleasant*) to 5 (*pleasant*) and arousal rated 1 (*calm*) to 5 (*excited*). In the evaluation section, each of the IAPS pictures was presented together with the SAM scales on the display, and participants chose the valence and arousal values without any time pressure. The presentation order of the IAPS pictures was randomized. The target pictures were not evaluated. During the experiment, participants were seated in a reclining chair in a sound-attenuated and electrically shielded room.

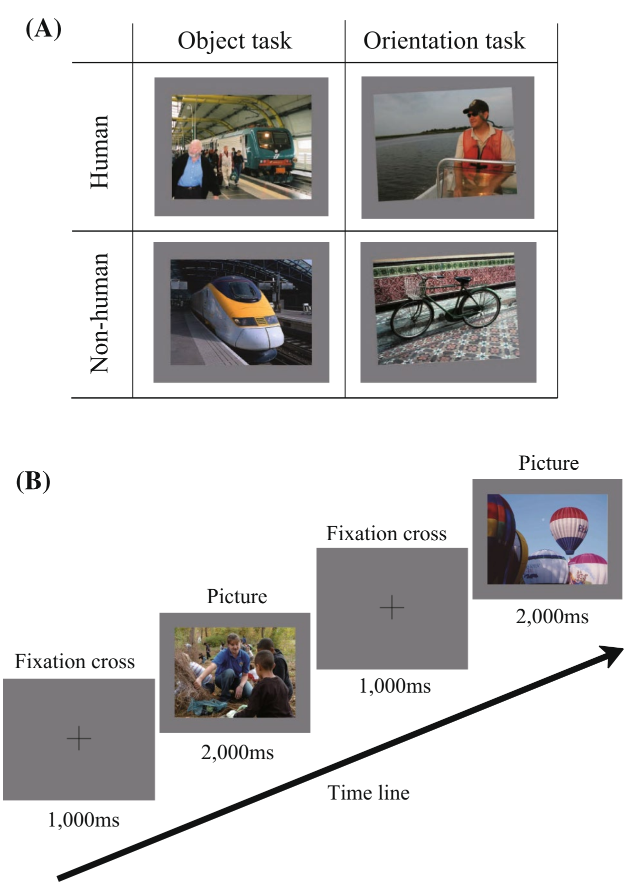

Fig. 2 **a** Examples of target pictures in the object task (*left*) and the orientation task (*right*). **b** Schematic illustration of experimental procedure

EEG recordings

The EEG signals were acquired with a digital amplifier (Nihon-Kohden, Neurofax EEG1100), and silver–silver chloride electrodes were placed at 27 scalp sites: Fp1, Fp2, F7, F3, Fz, F4, F8, FCz, T3, C3, Cz, C4, T4, CPz, T5, P3, Pz, P4, T6, PO7, PO8, O1, Oz, O2, O9, Iz, and O10, according to the extended international 10–20 system, with AFz as the ground electrode. The EEGs were re-referenced to mathematically averaged earlobes (A1–A2) offline. To monitor blinks and eye movements, vertical and horizontal electrooculograms (EOGs) were acquired using electrodes placed above and below the right eye, and the outer left and right canthi, respectively. The impedance of all electrodes was kept below 10 kΩ. The EEGs and EOGs were digitized at a sampling rate of 1000 Hz and the time constant was set at 10 s. All EEG and EOG signals were low-pass-filtered at 30 Hz with a second-order Butterworth filter.

Data analysis

The data from two male participants were excluded from the analyses because of extensive noise; more than 47 % of trials could not be used for averaging in these participants. Thus, we analyzed the data from 34 participants (16 females). The time epoch for computing ERPs was set at −100 to 2000 ms relative to the onset of the pictures. Independent component analysis was adopted to remove eye-blink-related components, using EEGLAB version 11.0.4.3b (Delorme and Makeig 2004). The epochs in which the signal changes exceeded ±80 μV on any of the EEGs were excluded from analysis (7.5 % of epochs on average). ERPs were evaluated relative to a 100 ms pre-stimulus baseline.

We estimated the mean amplitudes of LPP within two time windows, from 350 to 650 and from 550 to 900 ms after the onset of the pictures. The 350–650 ms window was examined because a prominent positive component (possibly including a P3 component) was observed with a peak at around 500 ms after the onset of the pictures. The 550–900 ms window was evaluated because the differential amplitude between unpleasant and neutral categories (i.e., the valence effect) reached an asymptote at around 550 ms and remained at least until 900 ms after the onset of the pictures. The mean amplitude was calculated by averaging the waveform of the parietal sites (i.e., P3, Pz, and P4) in each time window (i.e., 350–650 and 550–900 ms) for each combination of valence (pleasant, neutral, and unpleasant) × content (human vs. non-human) × task (object vs. orientation). Note that trials in which the target was presented were removed from the analyses.

The mean amplitudes were subjected to a mixed ANOVA with sex (male vs. female), valence (pleasant, neutral, and unpleasant), content (human vs. non-human), and task (object vs. orientation), with sex as the between-participants variable and the others as within-participants variables. For behavioral performance, correct response times, hit rates, and false alarm rates were calculated. Each result was subjected to a mixed ANOVA by sex (male vs. female) and task (object vs. orientation). In addition, the valence and arousal scores acquired in evaluation section were subjected to a mixed ANOVA by sex (male vs. female), valence (pleasant, neutral, and unpleasant), and content (human vs. non-human).

Results

ERPs

Grand-average ERPs for the effects of valence, content, and task are shown in Fig. 3. For the effect of valence, the waveforms elicited by the unpleasant pictures were more positive around the parietal sites than were those elicited by the pleasant and neutral pictures; this is the LPP component. Figure 4a shows the average ERPs at the parietal sites (collapsed across P3, Pz, and P4). These evinced a large positive component with a peak latency of about 500 ms, most notably in the waveforms elicited by the non-human pictures. For the statistical analyses, the mean amplitudes of LPP were computed by averaging the waveforms of the parietal sites within the 350–650 ms time window (i.e., 500 ± 150 ms). The mean amplitudes are shown in Table 2. A sex (2) × valence (3) × content (2) × task (2) ANOVA revealed significant main effects of valence (unpleasant > pleasant > neutral), $F(2, 64) = 29.5$, $p < .001$, $\eta_p^2 = .480$, content (human > non-human), $F(1, 32) = 6.26$, $p < .05$, $\eta_p^2 = .164$, and task (object task > orientation task), $F(1, 32) = 20.77$, $p < .001$, $\eta_p^2 = .394$. The sex × content interaction was significant, $F(1, 32) = 4.75$, $p < .05$, $\eta_p^2 = .129$. Post hoc analyses with Bonferroni correction indicated significantly larger amplitudes for the human relative to the non-human pictures in females ($p < .01$) but not in males ($p = .81$). The valence × content interaction was also significant, $F(2, 64) = 13.47$, $p < .001$, $\eta_p^2 = .296$. Post hoc analyses with Bonferroni correction indicated significantly larger amplitudes for the unpleasant non-human pictures relative to the pleasant and neutral non-human pictures (*ps* < .001). Amplitudes were also significantly larger for the pleasant non-human pictures than for the neutral non-human ones ($p < .01$). On the other hand, the amplitudes were significantly larger for the unpleasant human pictures than for the neutral human pictures ($p < .05$), but no significant differences were observed between the other human picture pairs (*ps* > .18).

Figure 4b shows pleasant-minus-neutral and unpleasant-minus-neutral difference waveforms (collapsed across two tasks and human/non-human pictures). These waveforms demonstrate that the amplitude difference between unpleasant and neutral categories reached an asymptote at around 550 ms and remained at least until 900 ms after the onset of the pictures. Therefore, we also examined the mean amplitudes of LPP for the 550–900 ms time window. The mean amplitudes are shown in Table 3. A sex (2) × valence (3) × content (2) × task (2) ANOVA revealed significant main effects of valence (unpleasant > pleasant > neutral), $F(2, 64) = 48.6$, $p < .001$, $\eta_p^2 = .603$, content (human > non-human), $F(1, 32) = 30.8$, $p < .001$, $\eta_p^2 = .490$, and task (object task > orientation task), $F(1, 32) = 10.43$, $p < .01$, $\eta_p^2 = .246$. The sex × valence × content interaction was also significant, $F(2, 32) = 3.17$, $p < .05$, $\eta_p^2 = .090$. The main effect of sex and other interactions were not significant (*ps* > .16). The sex × valence × content interaction was examined using two-way ANOVAs by sex and content for each valence. For the pleasant pictures, the main effect of content was significant, $F(1, 32) = 26.81$, $p < .001$, $\eta_p^2 = .456$, but the main effect of sex and the interaction

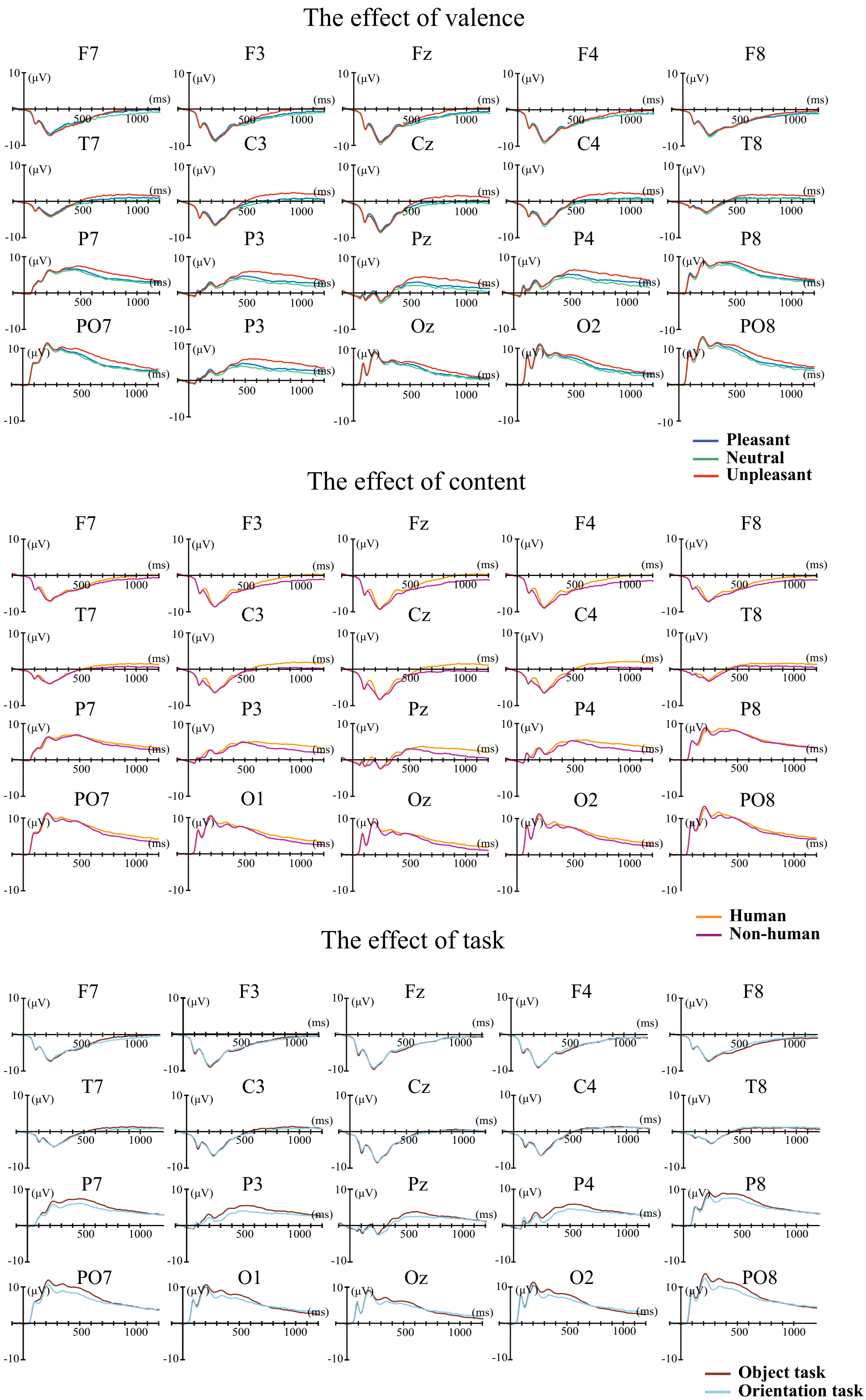

Fig. 3 Grand-average ERPs at F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, PO7, PO8, O1, Oz, and O2, demonstrating effects of valence (*top*), content (*middle*), and task (*bottom*) separately

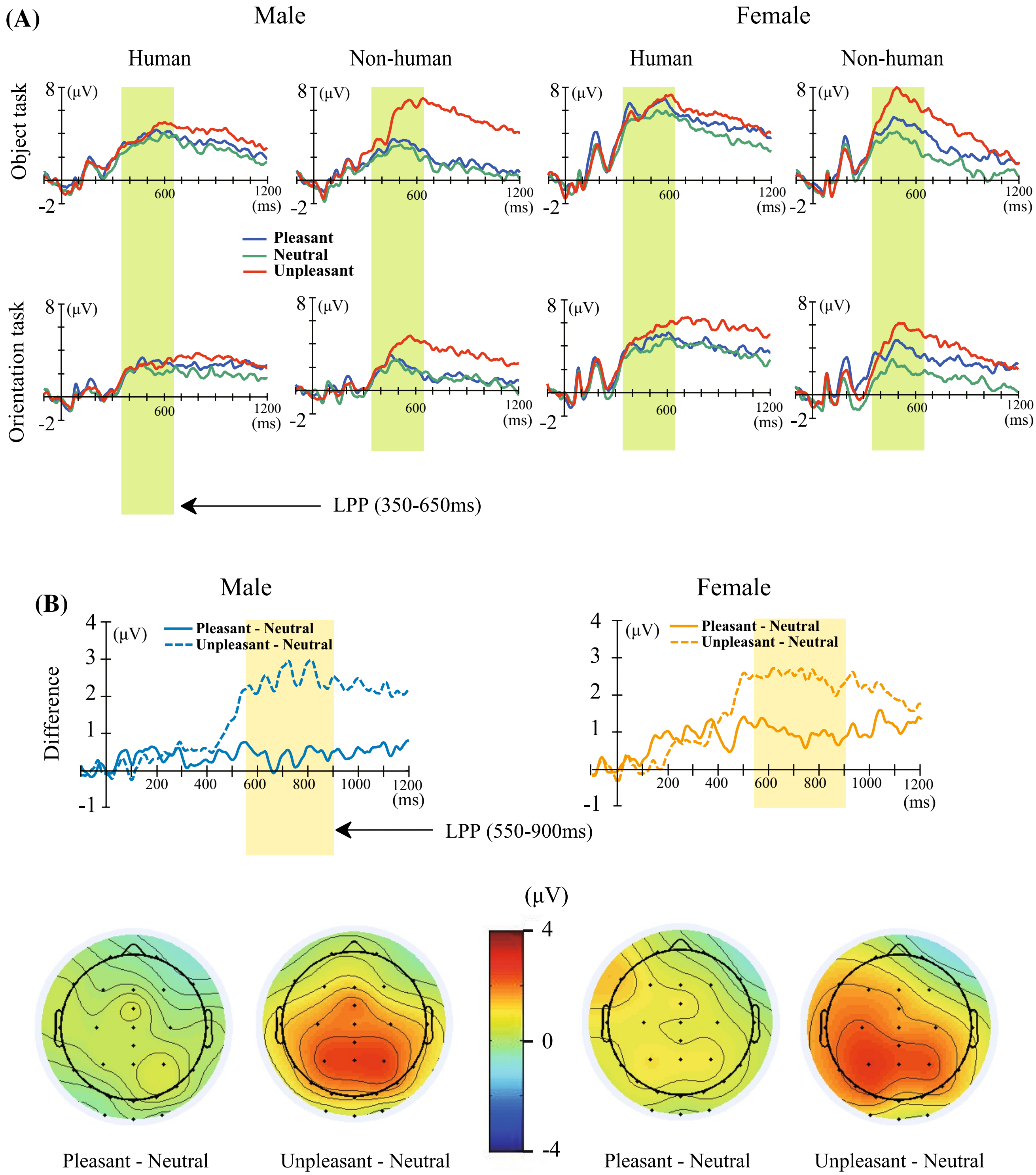

Fig. 4 **a** Grand-average ERPs at parietal sites (i.e., averaged across P3, Pz, and P4) for sex × valence × content × task. **b** Pleasant-minus-neutral and unpleasant-minus-neutral difference waves (collapsed across two tasks and human/non-human pictures) and topographical maps representing mean amplitude of the LPP range (550–900 ms)

Table 2 Mean and standard deviation of LPP amplitude (μV) with the time window of 350–650 ms in each condition

Picture category	Female		Male	
	Object task (SD)	Orientation task (SD)	Object task (SD)	Orientation task (SD)
Human				
Pleasant	6.26 (1.21)	4.47 (1.15)	3.82 (.83)	2.72 (.79)
Neutral	5.52 (1.00)	3.89 (1.08)	3.35 (.82)	2.22 (.68)
Unpleasant	6.33 (1.34)	5.12 (1.08)	4.05 (.93)	2.65 (.75)
Non-human				
Pleasant	4.62 (1.06)	3.78 (1.11)	2.96 (.83)	2.11 (.63)
Neutral	3.41 (1.02)	2.09 (1.00)	2.45 (.80)	1.91 (.73)
Unpleasant	6.54 (1.41)	4.99 (1.05)	5.45 (.94)	3.51 (.65)

Table 3 Means and standard deviations of LPP amplitude (μV) within the 550–900 ms time window in each condition

Picture category	Female		Male	
	Object task (SD)	Orientation task (SD)	Object task (SD)	Orientation task (SD)
Human				
Pleasant	5.55 (1.10)	4.42 (1.09)	3.69 (.72)	2.74 (.67)
Neutral	4.86 (.95)	4.16 (1.04)	3.26 (.61)	2.10 (.56)
Unpleasant	6.26 (1.28)	6.00 (1.13)	4.59 (.76)	3.27 (.71)
Non-human				
Pleasant	3.30 (1.02)	3.16 (.98)	1.96 (.69)	1.33 (.50)
Neutral	1.99 (.97)	1.66 (.92)	1.50 (.63)	1.26 (.66)
Unpleasant	5.34 (1.35)	4.79 (1.35)	6.29 (.81)	3.80 (.53)

Table 4 Mean and standard deviation of correct response time (s), hit rate, and false alarm rate in each condition

	Female		Male	
	Object task (SD)	Orientation task (SD)	Object task (SD)	Orientation task (SD)
Correct response time (s)	.68 (.02)	.73 (.04)	.66 (.03)	.77 (.04)
Hit rate	.95 (.01)	.94 (.01)	.96 (.01)	.91 (.02)
False alarm rate	.0009 (.0004)	.0019 (.0005)	.0014 (.0004)	.0018 (.0006)

between sex and content were not significant (*ps* > .17). For the neutral pictures, significant effects were found for content, F (1, 32) = 47.40, $p < .001$, $\eta_p^2 = .597$, and for the sex × content interaction, F (1, 32) = 5.64, $p < .05$, $\eta_p^2 = .150$, but not for sex ($p = .341$). Post hoc analyses with Bonferroni correction indicated that amplitudes were significantly larger for human relative to non-human pictures in both males ($p < .01$) and females ($p < .001$). For the unpleasant pictures, the sex × content interaction was significant, F (1, 32) = 13.08, $p = .001$, $\eta_p^2 = .290$, but no significant main effects were observed (*ps* > .53). Post hoc analyses with Bonferroni correction indicated that the amplitudes were significantly larger for the non-human relative to the human pictures in males ($p < .05$). On the other hand, in females, amplitudes were significantly larger for the human pictures than for the non-human pictures ($p < .01$).

Task performance

Mean correct response times, hit rates, and false alarm rates are shown in Table 4. For correct response times, a sex (2) × task (2) ANOVA revealed a significant main effect of task (orientation task > object task), F (1, 32) = 12.8, $p = .001$, $\eta_p^2 = .285$, but the main effect of sex and the interaction were not significant (*ps* > .22). For hit rates, a sex (2) × task (2) ANOVA revealed a significant main effect of task (object task > orientation task), F (1, 32) = 7.07, $p < .05$, $\eta_p^2 = .181$, but the main effect of sex and the interaction were not significant (*ps* > .15). For false alarm rates, a sex (2) × task (2) ANOVA revealed a significant main effect of task (orientation task > object task), F (1, 32) = 4.36 $p < .05$, $\eta_p^2 = .120$; again, the main effect of sex and the interaction were not significant (*ps* > .42).

Evaluation scores

Figure 1 shows the mean valence and arousal scores acquired in the evaluation section. For the valence scores, a sex (2) × valence (3) × content (2) ANOVA revealed significant main effects of valence (pleasant > neutral > unpleasant), F (2, 64) = 293.575, $p < .001$, $\eta_p^2 = .902$, and content (human > non-human), F (1, 32) = 22.2, $p < .001$, $\eta_p^2 = .410$. Significant interactions were observed for sex × valence, F (2, 64) = 5.57, $p < .05$, $\eta_p^2 = .148$, and valence × content, F (2, 64) = 20.0, $p < .001$, $\eta_p^2 = .385$. The main effect of sex and other interactions were not significant (*ps* > .13). Post hoc analyses with Bonferroni correction of the sex × valence interaction revealed that pleasant pictures were evaluated higher by females than by males ($p < .05$), whereas no sex difference was observed for the neutral and unpleasant pictures (*ps* > .15). Post hoc analyses with Bonferroni correction of the valence × content interaction indicated that the human pictures in the unpleasant category were evaluated less negatively relative to the non-human pictures in the unpleasant category ($p < .001$), whereas there was no significant difference between human and non-human pictures in the pleasant and neutral categories (*ps* > .19).

For the arousal scores, a sex (2) × valence (3) × content (2) ANOVA revealed significant main effects of valence (unpleasant > pleasant = neutral), F (2, 64) = 46.4, $p < .001$, $\eta_p^2 = .592$, and content (human > non-human), F (1, 33) = 17.1, $p < .001$, $\eta_p^2 = .348$. The sex × valence × content interaction was also significant, F (2, 64) = 3.41, $p < .05$, $\eta_p^2 = .096$. The main effect of sex and other interactions were not significant (*ps* > .17). The sex × valence × content interaction was decomposed by means of two-way ANOVAs by sex and content for each valence. For the pleasant pictures, the main effect of content was significant (human > non-human), F (1, 32) = 17.09, $p < .001$, $\eta_p^2 = .348$, but the main effect of sex and the interaction were not significant (*ps* > .37). For the neutral pictures, there was a significant main effect of content (human > non-human), F (1, 32) = 62.67, $p < .001$, $\eta_p^2 = .662$, and a significant sex × content interaction, F (1, 32) = 6.79, $p < .05$, $\eta_p^2 = .175$, but the main effect of sex was not significant ($p = .251$). Post hoc analyses with Bonferroni correction indicated that human pictures in the neutral category were evaluated higher relative to non-human pictures in the neutral category in both males ($p = .001$) and females ($p < .001$). For the unpleasant pictures, the main effects of content (non-human > human), F (1, 32) = 8.48, $p < .01$, $\eta_p^2 = .210$, and sex (female > male), F (1, 32) = 4.18, $p < .05$, $\eta_p^2 = .116$, were significant, but the interaction was not significant ($p = .64$).

Discussion

In the present study, we examined whether or not the presence of human images in emotional pictures enhanced sex-related effects on LPP even when the valence levels of human and non-human pictures were controlled. We first discuss the results for LPP within the later time window (550–900 ms) because an important interaction related to the sensitivity to humans in females (i.e., the sex × valence × content interaction) was observed in this time window. Sex-related effects were observed especially in the unpleasant category. In the valence evaluations provided by each participant, the unpleasant non-human pictures were rated more negatively than the unpleasant human pictures, but no significant sex-related effect was observed. The results for LPP (550–900 ms) amplitudes showed the following effects: in females, for pictures in the unpleasant category, viewing human pictures elicited larger LPP than viewing non-human pictures. On the other hand, in males viewing unpleasant pictures, LPP amplitudes were smaller for human pictures than for non-human pictures. Previous studies have repeatedly reported that more emotional pictures elicit larger LPP (e.g., Dunning and Hajcak 2009). This is consistent with the present results for males, who showed larger LPP amplitudes and lower valence scores (i.e., evaluated more negatively) for unpleasant non-human pictures relative to unpleasant human pictures. In contrast, females showed larger LPP with *less* emotional human pictures. The inconsistency between the LPP amplitude and the valence level observed in females strongly supports the hypothesis that sensitivity to human pictures is greater in females than in males (Althaus et al. 2014; Groen et al. 2013; Proverbio et al. 2009). That is, the present results revealed that, even if the pictures they view have less negative impact, females are likely to evince heightened sensitivity to humans and greater neural responses when they view human pictures.

As Weinberg and Hajcak (2010) proposed, LPP amplitudes are influenced not only by valence level but also by arousal level. They reported that emotional pictures that were rated high in arousal, such as mutilation pictures, elicited larger LPP than low-arousal pictures. In the present study, arousal was rated higher for the unpleasant non-human pictures than for the unpleasant human pictures by both females and males. The results of Weinberg and Hajcak (2010) predict that viewing high-arousal pictures (i.e., unpleasant non-human pictures) would produce greater LPP amplitude than viewing low-arousal pictures (i.e., unpleasant human pictures). However, this was not the case in females. The present results imply that sensitivity to humans in females is achieved independent of both the arousal levels of pictures and their valence levels. Previous studies that reported sex-related effects in LPP amplitude used unpleasant human pictures having great negative impact (e.g., mutilation; Althaus et al. 2014; Groen et al. 2013; Proverbio et al. 2009). Thus, it was unclear whether the larger LPP elicited by human pictures in females could be attributed to greater sensitivity to humans or to higher valence and arousal levels of the pictures. The present study provides the first evidence that an increase of sensitivity to human pictures in females occurs even when the human pictures have less emotional impact than the non-human pictures.

Although the sex-related effect in sensitivity to humans could be observed for pictures in the unpleasant category, no such effect was observed for pictures in the pleasant category; in both females and males, LPP amplitudes were larger for human pictures than for non-human pictures. Pleasant human and non-human pictures received similar positive valance scores, but arousal scores of pleasant pictures were higher for human than for non-human pictures; again, this occurred in both females and males. The results of LPP amplitude for the pleasant category are consistent with the notion that viewing higher arousal pictures elicits larger LPP (Weinberg and Hajcak 2010). These results indicate that females showed greater sensitivity to humans only when they viewed unpleasant pictures. Why didn't their greater sensitivity to humans appear when they viewed pleasant pictures? A possible explanation for the absence of sex-related effect in the pleasant category is that females evince greater sensitivity to humans only when they view unpleasant pictures. Schupp et al. (2004) proposed that people are sensitive to fear-relevant faces relative to friendly faces, because negative information is essential to escape and avoidance. Based on this notion, it is possible that females show greater sensitivity to other people only when the people depicted in the picture show negative emotion or when the context of the picture is negative. It should be noted that, a previous study focusing on the N2 component reported the sex-related effect in the pleasant category even if the valence and arousal levels of human and non-human pictures were controlled (Proverbio et al. 2008). In addition, Maffei et al. (2015) examined the sex-related effect on the subjective feelings during viewing various types of movie clips (i.e., erotic, scenery, neutral, sadness, compassion, and fear movie clips) and proposed that clustering in more detailed categories (beyond the positive, neutral, and negative categories) is necessary for the examination of sex-related effects on emotion. Further studies are needed to clarify this issue.

We also analyzed LPP within the earlier time window (350–650 ms). These results showed that viewing human pictures elicited larger LPP than non-human pictures only in females. This indicates that females, but not males, were able to distinguish human from non-human pictures at an earlier processing stage. In the earlier time window, the sex-related effect on "emotional" human pictures (i.e., the sex × valence × content interaction) was not observed, whereas this effect was significant for LPP within the later time window. These results imply that sensitivity to humans in females first increases irrespective of the emotional context of pictures; then, greater sensitivity occurs selectively for unpleasant human pictures. Eimer and Holmes (2002) proposed that the processes of distinguishing a human presence in a picture and recognizing the emotional context of the picture are performed in parallel. It is possible that these processes affected females' sensitivity to humans on different time courses.

In the present study, we also investigated whether or not the sex-related effects depend on attentional processing of the pictures. To this end, two types of task were evaluated, an object task and an orientation task. In all valence categories, the amplitudes of LPP elicited by the object task were larger than those elicited by the orientation task. This result is consistent with the assumption that the object task requires more attentional processing of pictures than the orientation task. It is known that the amplitude of LPP is greater when participants pay attention to pictures relative to when they pay attention to letters surrounding the pictures (Wiens et al. 2011). In the present study, the sex × valence × content × task interaction was not significant ($p = .49$). This suggests that the sensitivity to humans could be observed irrespective of the tasks used in the present study, implying that the female sensitivity to humans can be achieved in a robust manner. That is, even if females pay less attention to the content of pictures, they may nevertheless show greater sensitivity to humans. Of course, it is also possible that the present study was underpowered to detect the effect of attention. Further studies are needed to clarify whether or not the increase of sensitivity to humans in females is achieved independently of task requirements. Note that the effect of task at parietal–occipital sites was observed at a much earlier stage (around 300 ms), as shown in Fig. 3. However, we do not discuss this effect here, because effects unrelated to sex are beyond the scope of the present study.

In the present study, we examined sex-related effects in the amplitudes of LPP as one of the critical factors involved in individual differences. Because it has been proposed that the amplitude of LPP could be influenced not only by sex but also by other factors, such as age (Autumn et al. 2013) and personality (Speed et al. 2015), further studies to examine the effects of these factors and their interactions are needed to advance the understanding of individual differences in emotion.

In conclusion, the present study revealed sex-related effects in the inconsistency between LPP amplitude and valence level. In females, larger LPP amplitudes with the time window of 550–900 ms were elicited when viewing unpleasant human pictures than when viewing unpleasant non-human pictures, even when the human pictures were less negatively evaluated relative to the non-human pictures. In contrast, in males, the result for LPP amplitudes accorded with evaluation scores. The results suggest that relatively robust processes in females cause sex-related effects in sensitivity to human pictures.

Appendix

IAPS images:

Pleasant human [mean luminance: 24.87 cd/m^2 (SD: 1.82)], 1340, 1601, 2040, 2050, 2057, 2058, 2070, 2071, 2080, 2091, 2150, 2160, 2165, 2170, 2208, 2209, 2216, 2222, 2224, 2260, 2299, 2304, 2310, 2311, 2331, 2340, 2341, 2345, 2346, 2352, 2360, 2370, 2387, 2391, 2395, 2501, 2510, 2530, 2540, 2550, 2650, 2655, 2660, 4603, 4614, 4622, 4626, 4700, 7325, 8034, 8090, 8120, 8200, 8300, 8350, 8370, 8380, 8420, 8461, 8470, 8490, 8496, 8497, 8540.

Neutral human [mean luminance: 17.92 cd/m^2 (SD: 1.63)], 2190, 2191, 2200, 2210, 2214, 2215, 2220, 2221, 2230, 2235, 2250, 2272, 2280, 2357, 2372, 2381, 2383, 2385, 2389, 2393, 2394, 2435, 2440, 2441, 2480, 2485, 2487, 2493, 2495, 2499, 2514, 2516, 2518, 2570, 2575, 2579, 2580, 2595, 2600, 2616, 2620, 2635, 2702, 2749, 2780, 2810, 2830, 2840, 2850, 2870, 2890, 4605, 8010, 8040, 8041, 8060, 8160, 8232, 8311, 8340, 9070, 9402, 9411, 9700.

Unpleasant human [mean luminance: 21.53 cd/m^2 (SD: 1.80)], 2053, 2055.1, 2100, 2110, 2120, 2141, 2276, 2278, 2312, 2399, 2455, 2490, 2590, 2661, 2683, 2688, 2691, 2694, 2700, 2710, 2715, 2750, 2753, 2795, 2900, 3022, 3160, 3220, 3280, 3300, 6010, 6211, 6213, 6242, 6244, 6250.1, 6311, 6312, 6530, 6550, 6555, 6561, 6571, 6830, 6834, 6836, 6838, 6840, 6940, 8230, 8231, 9007, 9041, 9046, 9160, 9190, 9331, 9341, 9404, 9409, 9415, 9432, 9530, 9584.

Pleasant non-human [mean luminance: 24.48 cd/m^2 (SD: 1.48)], 1440, 1460, 1463, 1500, 1510, 1540, 1590, 1600, 1610, 1620, 1710, 1721, 1722, 1731, 1740, 1750, 1920, 5000, 5001, 5010, 5200, 5201, 5220, 5260, 5270, 5300, 5450, 5480, 5551, 5594, 5600, 5611, 5660, 5700, 5760, 5779, 5780, 5811, 5820, 5891, 5910, 5982, 5994, 7200, 7220, 7230, 7260, 7270, 7280, 7330, 7350, 7390, 7400, 7410, 7430, 7470, 7480, 7501, 7545, 7570, 8170, 8500, 8501, 8502.

Neutral non-human [mean luminance: 26.20 cd/m^2 (SD: 1.72)], 1560, 5020, 5250, 5390, 5520, 5535, 5593, 5661, 5720, 5731, 5740, 5800, 5900, 6000, 6150, 7000, 7002, 7004, 7006, 7009, 7010, 7020, 7025, 7030, 7031, 7034, 7035, 7038, 7040, 7041, 7050, 7060, 7080, 7090, 7100, 7110, 7150, 7161, 7170, 7175, 7180, 7184, 7185, 7186, 7187, 7190, 7195, 7211, 7217, 7224, 7233, 7234, 7235, 7236, 7320, 7490, 7491, 7504, 7700, 7705, 7710, 7820, 7830, 7950.

Unpleasant non-human [mean luminance: 23.91 cd/m^2 (SD: 1.80)], 1050, 1051, 1052, 1090, 1110, 1113, 1200, 1205, 1270, 1274, 1275, 1280, 1300, 1301, 1525, 1930, 1932, 2692, 2722, 2981, 5971, 5972, 6020, 6190, 6200, 6210, 6230, 6241, 6610, 7359, 7361, 7380, 9000, 9001, 9008, 9090, 9102, 9110, 9140, 9180, 9181, 9182, 9280, 9290, 9300, 9301, 9320, 9340, 9373, 9390, 9440, 9470, 9471, 9480, 9495, 9600, 9611, 9620, 9621, 9622, 9630, 9830, 9911, 9912.

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