



Does aesthetic judgment on face attractiveness affect neural correlates of empathy for pain? A fNIRS study

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Abstract

Empathy for pain is at the basis of altruistic behaviors and is known to be modulated by variables such as group membership, pleasantness or unpleasantness of situations and social relationships. Also, face attractiveness and aesthetic judgment might play a role when observing a person in painful conditions, by increasing individuals' empathic responsiveness. Indeed, physical attractiveness can modify both the perception of the face itself and its reception in a social context. In the present study, we aimed to assess cortical activity when attention is focused on the aesthetic features of an individual showing painful feelings. Brain activity (optical imaging: functional near-infrared spectroscopy, fNIRS), considered in its hemodynamic components (oxygenated [oxy-Hb] and deoxygenated hemoglobin [deoxy-Hb]) was monitored when 22 subjects ($M_{age} = 24.9$; $SD = 3.6$) observed faces (attractive; unattractive) that received painful stimulations (pain; no pain) and were asked to judge the attractiveness and pain condition of the face. Specifically, we targeted the left and right inferior frontal gyrus (IFG), sensory cortex, and temporo-parietal junction (TPJ). Analyses revealed significant lower oxy-Hb levels in left IFG compared to right hemispheric channels when asking participants to rate faces attractiveness independently from the stimulus features. Besides, lower levels of deoxy-Hb were detected in the right TPJ for unattractive faces compared to attractive faces. Overall, present findings highlighted that the formulation of an aesthetic judgment and face attractiveness plays a relevant role in empathic concerns and this seems to be able to overlay painful appraisal.

Article Highlights

- **The aesthetic judgment of face stimuli overlays the evaluation of pain conditions.**
- **A hemispheric lateralization effect related to emotion was found for right IFG.**
- **Bilateral preparietal somatosensory association areas are involved in aesthetic judgment.**
- **Unattractive faces triggered a cognitive empathic response modulated by the right TPJ.**

Keywords fNIRS · Face attractiveness · Empathy · Aesthetic judgment · Pain

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Introduction

Do we help a person whom we consider attractive when in a painful situation? Or do we feel more empathic towards an unattractive person who is in trouble? The observation of a person in a painful or distress condition produces a functional empathic response aimed to promote an evolutionary mechanism that drives to altruistic conduct (Singer et al. 2004; de Waal 2008; Batson 2014). However, it is still not clear whether this behavior may be influenced by the physical attractiveness of the person and whether attractiveness may act as a sort of amplifier of empathy for pain.

According to the perception–action model of empathy, empathic reactions frequently arise spontaneously, without a conscious (explicit) and demanding processing (Preston and de Waal 2002). In line with this, neuroimaging studies previously described that bottom-up neural networks consisting of the anterior insula and anterior cingulate cortex (ACC) are activated by perception of others in pain and specifically mediate first-person physical pain experience and emotional empathy (Singer et al. 2004; Botvinick et al. 2005; Jackson et al. 2005; Saarela et al. 2007; Lamm and Singer 2010; Shamay-tsoory 2015). While the cognitive process of comparing one’s perspective with the perspective of another person has been reflected by the top-down activation of the medial prefrontal cortex (mPFC) and temporo-parietal junction (TPJ) (Saxe and Kanwisher 2003). Specifically, TPJ has been previously associated to emotional regulation (Greccucci et al. 2013), social cognition (Allison et al. 2000) as well as to intentional agency (Van Overwalle 2009), and theory of mind (Frith and Frith 2003). Nevertheless, the empathic neural response is also modulated by other variables, such as the emotional bond between individuals (Singer et al. 2006), top-down attention to painful stimuli (Gu and Han 2007; Fan and Han 2008), social relationships and category membership (Hornstein 1972) and ethnic groups belonging (Johnson et al. 2002; Han et al. 2009; Xu et al. 2009).

Subjective reports of empathic concern have also been hypothesized to be influenced by face attractiveness (Fu et al. 2014). Our experience modulates our face prototype model and our aesthetic judgment in a dynamic way (Rhodes et al. 2003). The attractiveness aftereffect phenomenon is an excellent example of the dynamics of our face prototype. This effect was previously investigated by Fu and colleagues (2014) employing near-infrared spectroscopy (NIRS) and their strongest evidence regards the changes in neural responses in right inferior frontal gyrus (IFG). More specifically, the greater is the behavioral attractiveness aftereffect (with faces rated as more attractive), the greater the changes in the neural attractiveness effect in terms of decrease of the hemodynamic oxygenated blood [O₂Hb] activity in the right IFG. As the right IFG is consistently implicated in face attractiveness processing, this significant behaviour–neural response correlation suggests that this area may be sensitive specifically to attention towards stimulus features (Fu et al. 2014). In line with previous studies, the right IFG and have also been specifically found to be associated with the judgment of attractiveness (Haxby et al. 2000; Aharon et al. 2001; O’Doherty et al. 2003; Ishai 2007; Chatterjee et al. 2009; Liang et al. 2010).

This study aimed to check the impact of the physical attractiveness of the face in a situation associated with the sensation of pain. There are few reports in the literature about the impact of facial attractiveness on empathy, which nonetheless leads to ambiguous conclusion

(Jankowiak-Siuda et al. 2015). Physical attractiveness can modify both the perception of the face itself and its reception in a social context. Physically attractive people are considered to be healthier, to have a better set of genes and they are also assigned to many positive features (the so-called “halo effect”) (Dixson et al. 2003). Also, facial attractiveness affects the feeling of positive emotions (Mehrabian and Blum 1997). Moreover, when a person is involved in an aesthetic experience related to the evaluation of body stimuli, an attentional modulation of different cortical sensory regions involved in the perceptual processing of the perceived stimulus features is activated (Calvo-Merino et al. 2010; Kirsch et al. 2016). The somatosensory cortices are also engaged in the detection and interpretation of pain faces (Simon et al. 2006), and pain experiences and expressions always involve a conscious sensory perception of somatic sensations described to be singular and diverse from basic emotions correlates (Craig et al. 2001). However, still, the role of facial attractiveness and aesthetic judgment when observing a person in a painful condition is not clear.

Given these premises, in our study, we examined the cortical neural response patterns associated with the face attractiveness while participants were asked to rate the attractiveness of attractive and unattractive faces in painful or non-painful conditions. In the current study, we decided to explore the influence of physical attractiveness on empathy for pain utilizing fNIRS (functional NIRS) technique. To better understand the empathy for pain effect, we decide to draw the attention of the participants on the attractiveness and the pain of the face distinctly, as in Sheng and Han (2012) previous experiment. During the experimental procedure, fNIRS technique was used for measuring brain hemodynamic variations at the cortical level (15–25 mm underneath the scalp). fNIRS has been extensively used within the field of social neuroscience, ranging from the study of cognition, towards more complex emotional and interpersonal mechanisms. Despite the low time resolution if compared to an electroencephalogram, fNIRS system has a good spatial resolution, a low sensitivity to body movements, it is portable, easy to use, non-invasive, and makes possible for participants to view face stimuli in a more naturalistic way. It is a relatively low-cost tool, suitable for exploratory neuroscientific studies that aim to identify cortical regions involved in perceptual, cognitive and emotional processes.

In the present study, we first hypothesized an effect for attractive stimulus and for the perception of painful stimuli per se, without an explicit request to evaluate face attractiveness or pain condition. Second, we aim to compare the effect of explicit question on attractiveness and question on pain, to explore the direct relationship between the two explicit evaluation processes. Indeed, we expected an effect of attractiveness on pain perception when the explicit request to evaluate stimulus is focused on attractiveness. In addition, we aim

to verify the role of different cortical areas in the aesthetic judgment of pain stimuli and pain processing. Specifically, we opted to consider and focus on some specific brain areas: TPJ as a marker of emotional regulation mainly towards pain stimuli; IFG as an indicator of the face and its attractiveness processing; and prefrontal somatosensory association area for its midway modulation of aesthetic experience and pain face appraisal. Finally, we hypothesized that there might be a distinct lateralization effect for the cortical areas involved in physical attractiveness judgment, with the right hemisphere more active for stimuli with a negative connotation (painful and unattractive stimuli) and left hemisphere more active for stimuli with a positive connotation (attractive and non-painful stimuli).

Methods

Participants

22 healthy Caucasian subjects (5 males; $M_{\text{age}} = 24.9$; $SD = 3.6$; 2 left handed) were recruited from the Catholic University of the Sacred Heart, Milan, Italy. Inclusion criteria were normal, or corrected to normal, visual acuity, belonging to Caucasian ethnicity, age between 18 and 30. Exclusion criteria were: a history of psychiatric or neurological diseases; the presence of cognitive deficits; ongoing concurrent therapies based on psychoactive drugs that can alter central nervous system functioning; clinically relevant stress, anxiety; the occurrence of significant stressful life events during the last 6 months. All participants had a normal or corrected-to-normal vision. The respondents voluntarily agreed to participate in the study. They provided informed consent prior to participating in the study and they were debriefed after the experiment. This research was conducted following the principles and guidelines of the Helsinki Declaration and was approved by the Ethics Committee of the Department of Psychology of the Catholic University of the Sacred Heart.

Stimuli

Participants were shown a set of 60 stimuli of attractive (30; 15 female) and unattractive faces (30; 15 female) with a neutral facial expression. Stimuli were selected from The Chicago Face Database (Ma et al. 2015; <https://faculty.chicagobooth.edu/bernd.wittenbrink/cfd/index.html>) and internet website: models.com. The attractiveness of faces was assessed with a pre-validation procedure by 24 judges who rated 287 photos on a 5-point Likert scale. After this procedure, 60 stimuli were selected. These stimuli were presented in painful conditions (models had their cheek pricked with

a needle) and in the non-painful condition (the cheek was touched by Q-tip cotton fioc) with 1920×1200 inch for size.

Procedure

Participants were seated in a dimly lit room, facing a computer monitor that was placed 70 cm from the subject. Participants were informed that the aim of the study was to collect information about face perception. In addition, they were asked to answer “yes” or “no” on the “question about attractiveness” (“Does this person is attractive?”) and on the “question about pain” (“Does this person feel pain?”) when observing the stimuli. The two blocks were counter-balanced. The stimuli were presented using E-Prime software (E-prime2, Psychology Software Tool) running on a personal computer with a 15-in. screen. Participants were required to observe each stimulus during fNIRS measure recording, and they should attend to the images the entire time of exposition. 120 s resting baseline was registered at the beginning of the experiment before the picture series.

Each trial began with a fixation cross at the center of the computer screen that remained visible for 6 s. The fixation cross was replaced by a centrally presented face, which was displayed for a fixed duration of 1 s. Stimuli were presented in random order and were followed by a fixation cross visible for 6 s. During this interval, subjects were asked to rate faces attractiveness or pain (depending on the block and the two blocks were randomized). Inter-stimulus interval lasts 12 s, while the whole experimental procedure lasted approximately 1 h (Fig. 1).

fNIRS acquisition and analysis

fNIRS measurements were conducted with NIRScout System (NIRx Medical Technologies, LLC. Los Angeles, California) using an eight channel array of optodes (four light sources/emitters and four detectors) covering the frontal (Inferior Frontal Gyrus, IFG) and centro-parietal (Temporo Parietal Junction, TPJ) areas. Emitters were placed on the following positions: F7 and F8 for left and right IFG (BA 45–47); CP5 and CP6 for left and right TPJ; FZ for intermediate frontal (BA 08); CZ for prefrontal somatosensory association area (BA 05). While detectors were placed on: F5 and F6 for left and right IFG; P5 and P6 for left and right TPJ; F1 and F2 for left and right intermediate frontal; C1 and C2 for left and right prefrontal somatosensory association area (Fig. 2). Emitter–detector distance was kept at 30 mm for contiguous optodes and near-infrared light of two wavelengths (760 and 850 nm) was used. NIRS optodes were positioned on the subject’s head using a NIRS cap according to the international 10/5 system. Resulting channels are reported: Ch 1 (FZ–F1), Ch2 (FZ–F2), Ch3 (F7–F5), Ch4 (F8–F6), Ch5 (Cz–C1), Ch6 (Cz–C2), Ch7 (CP5–P5)

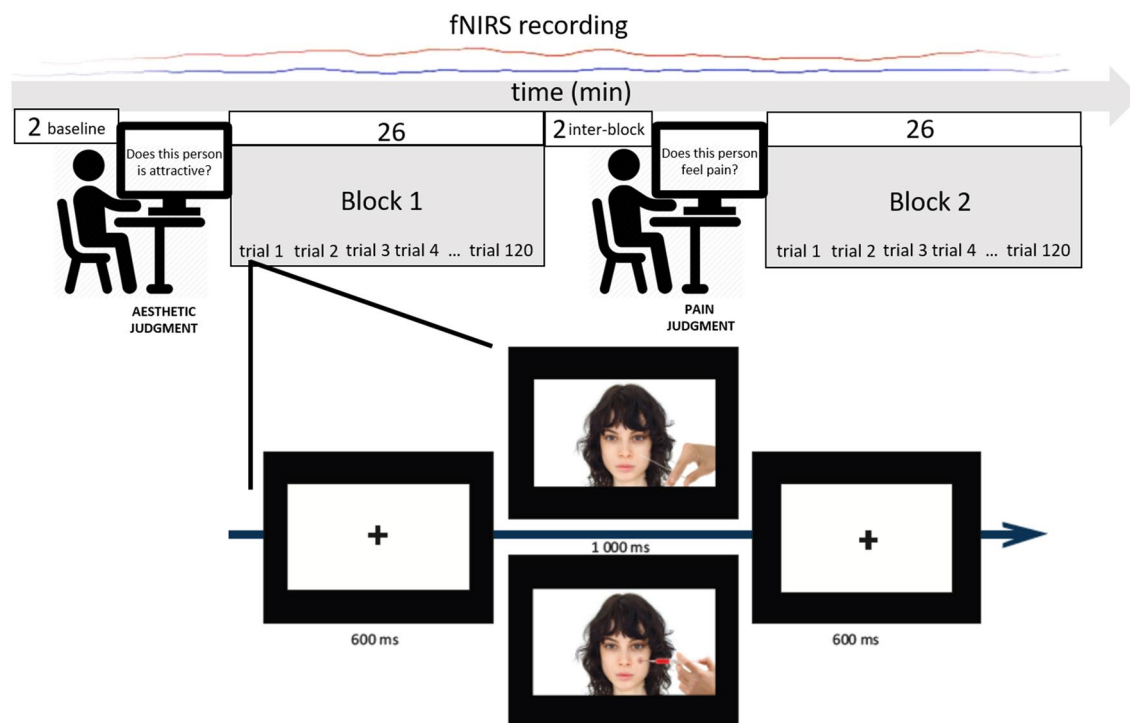


Fig. 1 Schematic illustration of the procedure

and Ch8 (CP6–P6). With NIRStar Acquisition Software, changes in the concentration of oxygenated (O2Hb) and deoxygenated hemoglobin (HHb) were recorded continuously throughout the task, starting from a 120 s resting baseline. Signals obtained from the eight NIRS channels were acquired with a sampling rate of 6.25 Hz and analyzed and transformed with nirsLAB software (v2014.05; NIRx Medical Technologies LLC, 15Cherry Lane, Glen Head, NY, USA), according to their wavelength and location, resulting in values for the changes in the concentration of oxy and deoxygenated hemoglobin for each channel, scaled in $\text{mmol} \cdot \text{mm}$. The raw O2Hb and HHb data from each channel were digitally band-pass filtered at 0.01–0.3 Hz. Then, the mean concentration of each channel was calculated by averaging data across the trials, an average value for each condition was calculated starting from the stimulus onset presentation for the following 6 s. The mean concentration value of 6 s before the trial was used as an event-related baseline. According to the mean concentrations in the time series, the effect size in every condition was calculated for each channel and subject. The effect sizes (Cohen's d) were calculated as the difference of the means of the baseline and trial divided by the standard deviation (sd) of the baseline: $D = (m1 - m2) / s$, with $m1$ and $m2$ being the mean concentration values during baseline and trial, respectively, and s the SD of the baseline. Then, the effect sizes obtained from the eight channels were averaged to increase the signal-to-noise

ratio. Although NIRS raw data were originally relative values and could not be directly averaged across subjects or channels, effect sizes normalized data could be averaged regardless of the unit since the effect size is not affected by differential pathlength factor (DPF).

Results

Data analysis

Behavioral data related to subjects' responses were analyzed in terms of accuracy during the two blocks. Response accuracies were calculated as the percentage of correct responses on the total responses for attractive/non-attractive and pain/non-pain stimuli. Chi-square analysis (χ^2) was applied to determine differences in the conditions attractive/non-attractive and pain/non-pain for behavioral data.

A set of four ANOVA models was applied to fNIRS-dependent measures (on both O2Hb and HHb), with question (2: question on attractiveness, question on pain); attractiveness (2: attractive, non-attractive); pain (2: pain, no pain); Channel (8: Ch1, Ch2, Ch3, Ch4, Ch5, Ch6, Ch7, Ch8) as within variables. For all the ANOVA tests, the degrees of freedom were corrected using Greenhouse–Geisser epsilon where appropriate. Post hoc comparisons (contrast analyses) were applied to the data.

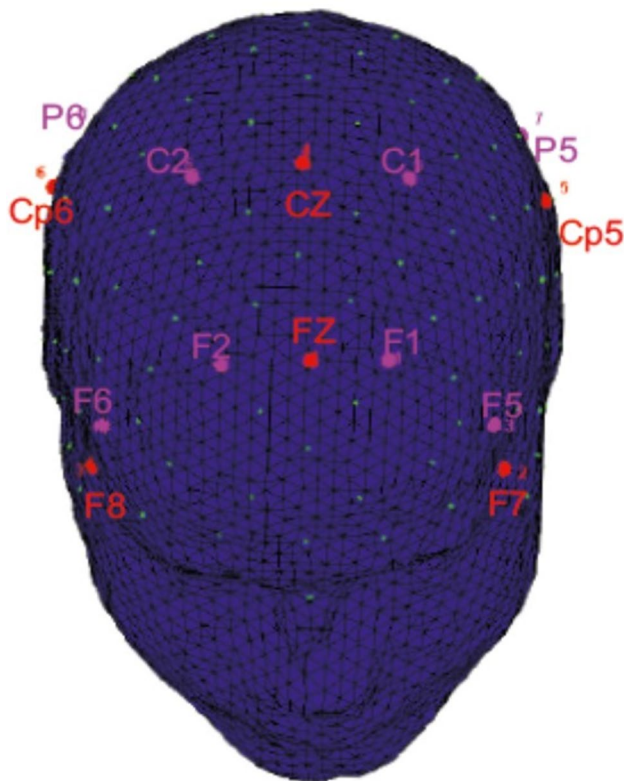


Fig. 2 Head rendering showing the location of fNIRS channels. Red for emitters: F7 and F8 for left and right IFG (BA 45–47); CP5 and CP6 for left and right TPJ; FZ for intermediate frontal (BA 08); CZ for preparietal somatosensory association area (BA 05). Purple for detectors: F5 and F6 for left and right IFG; P5 and P6 for left and right TPJ; F1 and F2 for left and right intermediate frontal; C1 and C2 for left and right preparietal somatosensory association area

Bonferroni test was applied for multiple comparisons. Also, the normality of the data distribution was preliminary tested (kurtosis and asymmetry tests). The normality assumption of the distribution was supported by these preliminary tests. Data were checked for outliers, and data > 3 standard deviation was deleted (Hoaglin et al. 1987). A p value of less than 0.05 was considered statistically significant for all the tests (Chi-square and ANOVA).

Behavioral data

Response accuracies were high for both questions on attractiveness and pain. For the block related to question on attractiveness, the accuracy was 97.11% for attractive pain stimuli; 97.45% for attractive no pain stimuli; for the block related to question on pain, the percentage of correctness was 98.34% for non-attractive pain stimuli; 97.87% for non-attractive no pain stimuli.

No significant differences were found in Chi-square analysis applied to attractive/non-attractive and pain/non-pain percentages (all $p > 0.050$).

fNIRS

The statistical analyses were applied to D-dependent measure for O2Hb and HHb concentration values.

For question on attractiveness, a main effect for “Channel” ($F[1,14] = 4.859$, $p \leq 0.050$, $\eta^2 = 0.25$) was found for O2Hb values (Fig. 3a, b). Pairwise comparisons revealed significant decrease of O2Hb for Channel 3 compared to Channel 4 ($p \leq 0.050$), Channel 5 ($p \leq 0.050$), Channel 6 ($p \leq 0.050$), and Channel 8 ($p \leq 0.050$). An interaction effect attractiveness \times channel ($F[1,16] = 2.367$, $p \leq 0.050$, $\eta^2 = 0.12$) was found for HHb values (Fig. 3c, d). Pairwise comparisons show significant difference ($p \leq 0.050$) for channel 8 (CP6–P6) between attractive and non-attractive condition.

Regarding the question on pain, no significant differences were found for O2Hb and HHb values (all $p > 0.050$). No significant differences were found for O2Hb and HHb in the interaction attractiveness \times pain \times channel (all $p > 0.050$) (Fig. 4a–d).

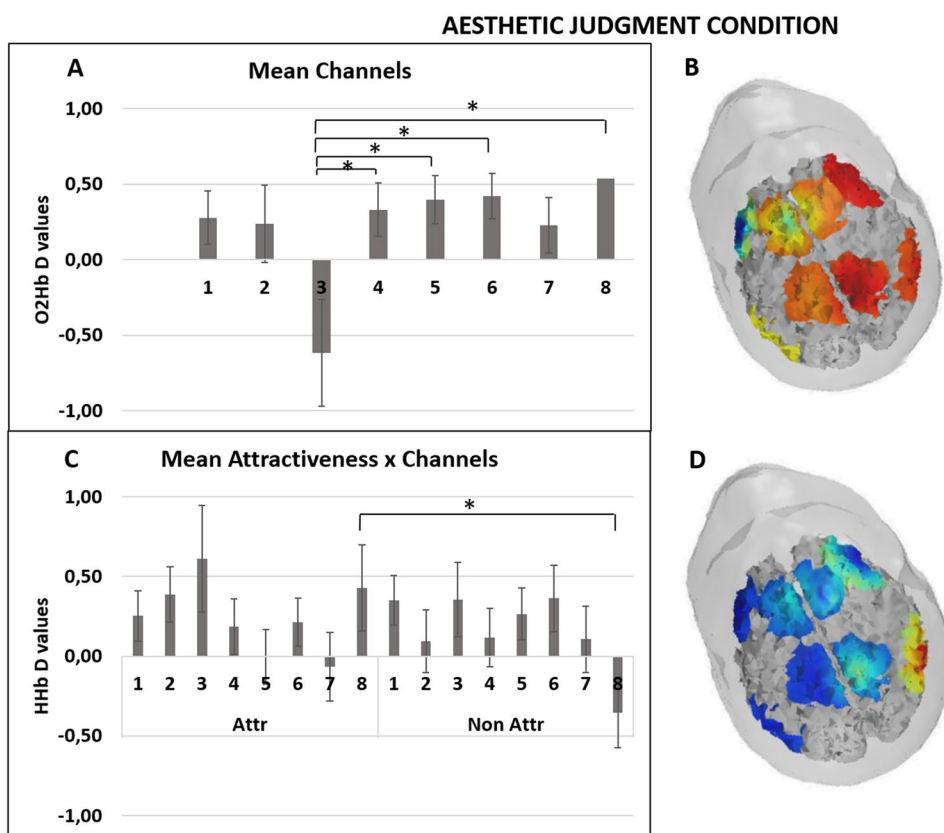
Discussion

This study provided new insights into the contribution of aesthetic judgment and attractiveness of face stimuli as variables involved in empathy for pain construct. Subjects were asked to evaluate explicitly attractiveness and pain condition of the same set of stimuli (attractive–unattractive and pain–no pain) in two different randomized experimental blocks (aesthetic judgment and pain judgment), to test a possible effect of attractiveness on empathic reaction fronting painful stimuli.

In neuroscience literature, the effect of facial attractiveness is well known and it was shown to be widespread in the brain involving the activation of subcortical and cortical neural structures (i.e., from amygdala to IFG, ACC, somatosensory areas, TPJ) (Aharon et al. 2001; O’Doherty et al. 2003; Ishai 2007; Chatterjee et al. 2009; Liang et al. 2010; Fu et al. 2014). However, to date, this is the first time fNIRS technique potential was exploited to verify the role of different cortical areas in the aesthetic judgment of pain stimuli and pain processing. Two main major findings were obtained.

First, a significant increase of O2Hb in an extended neural network including right IFG, right preparietal somatosensory association area, and right TPJ was found in comparison to left IFG, when participants were requested to express the aesthetic judgment. For left IFG, O2Hb values were

Fig. 3 **a** Bar graph shows significant differences in mean O2Hb D values for the eight Channels [Ch 1 (FZ–F1), Ch2 (FZ–F2), Ch3 (F7–F5), Ch4 (F8–F6), Ch5 (Cz–C1), Ch6 (Cz–C2), Ch7 (CP5–P5) and Ch8 (CP6–P6)] during the aesthetic judgement condition; **b** head representation of O2Hb variations (red color) in target channels: decrease O2Hb for left IFG (Ch 3), increase O2Hb for right IFG, preparietal somatosensory association areas (Ch 5 and Ch 6), and for right TPJ (Ch 6); **c** bar graph represents significant differences in mean HHb D values for right TPJ (Channel 8; CP6–P6, during the aesthetic judgement condition when participants observed unattractive compared to attractive stimuli; **d** head representation of HHb variations (blue color) shows a decreased of HHb in right TPJ for unattractive faces. For all charts, bars represent ± 1 SE; asterisks mark statistically significant differences with $p \leq 0.05$



lowest than other channels, signaling that this area might be sensitive to the explicit request to provide a judgment of attractiveness, independently from the stimulus. A possible explanation for this generalized effect might be that when asking subjects to evaluate stimulus attractiveness their attention shift to another evaluation level (the aesthetic one) that overlay the pain condition. Therefore, it is possible to suggest that, even in the context of empathy for pain, the empathic neural response can be modulated by other variables, such as the focus on the aesthetic judgment that was previously widely explored in neuroaesthetics studies and was demonstrated to involve specific frontal regions (Ishizu and Zeki 2013).

In addition, it is worth noticing that our result contains an interesting lateralization effect in the frontal brain regions with the right IFG more active than left IFG. This is partially in contrast with previous findings highlighting a variation (decrease) of O2Hb in right IFG when judging face as more attractive in the context of face perception (Fu et al. 2014). Nevertheless, right anterior hemisphere activity correlates with emotional elicitation (Schwartz et al. 1975), thus we suppose that this right IFG activation might be interpreted as a strong emotional implicit reaction to the request of expressing an aesthetic judgment. In line with this, it is possible to observe that the formulation of an aesthetic judgment masked the effect of pain. Therefore, conversely, the

increased right IFG activity may be considered as a significant effect of emotion regulation in reappraising facial stimuli from an aesthetic perspective, even if depicting neutral facial expression (Fusar-poli et al. 2009; Martin-Loeches et al. 2014). This interpretation is in line with the right hemisphere hypothesis, which postulates that the right half of the brain is specialized for processing all emotions, regardless of affective valence (Borod et al. 1998). While regarding the bilateral preparietal somatosensory association areas O2Hb increase, it is likely to depend on the participants' involvement in an aesthetic judgment task related to the evaluation of body stimuli (e.g., faces). In this context, an attentional modulation of different cortical sensory regions activity seems to be associated more to the perceptual processing of the perceived stimulus features than to attractiveness and pain variables.

Second, an effect was found for HHb levels with TPJ more sensitive to the presence or absence of physical attractiveness in facial stimuli. Specifically, right TPJ activation was detected as an answer to unpleasant unattractive stimuli compared to attractive stimuli. Indeed, the decrease of HHb levels could be read at first as an inverse activity index suggesting the presence of O2Hb in the right areas when the person is perceiving negatively connoted faces as unpleasant per se, independently from the pain condition. Previous basic research suggested that TPJ activity might be

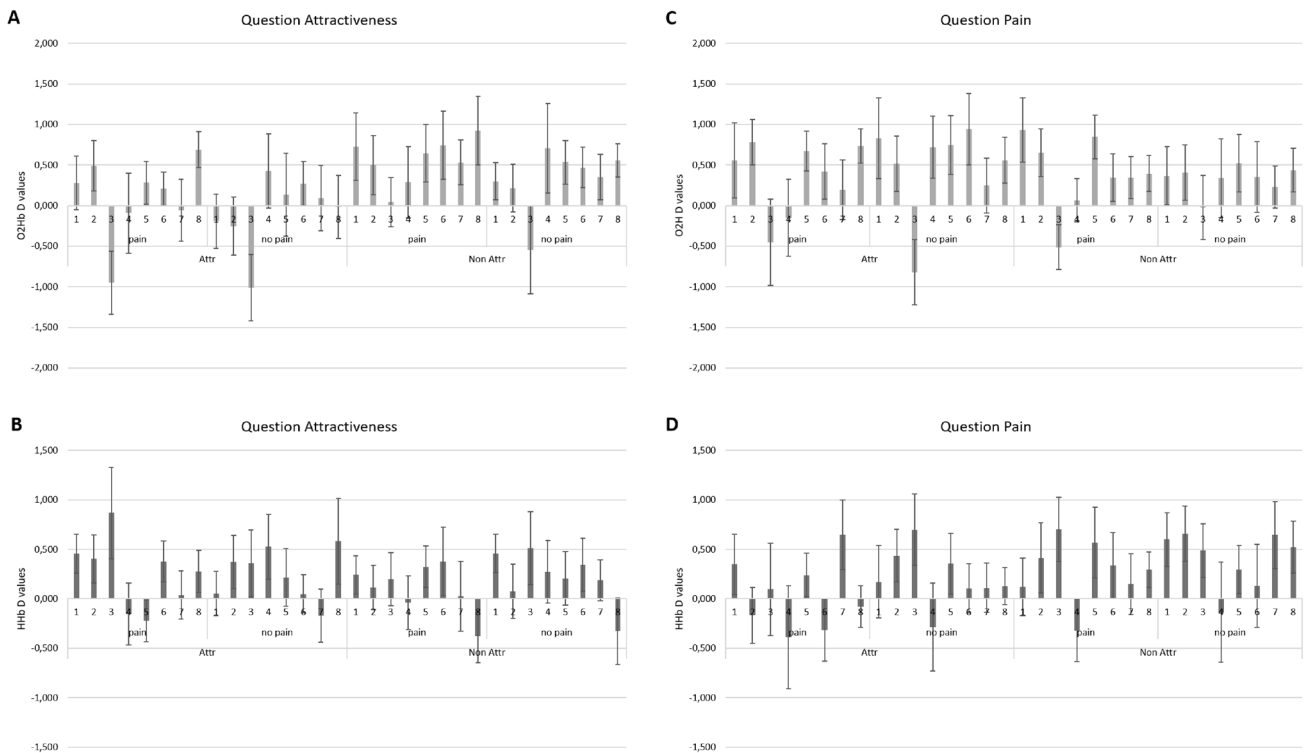


Fig. 4 Bar chart shows mean hemodynamic values of the interaction attractiveness × pain × channel [Ch 1 (FZ–F1), Ch2 (FZ–F2), Ch3 (F7–F5), Ch4 (F8–F6), Ch5 (Cz–C1), Ch6 (Cz–C2), Ch7 (CP5–P5) and Ch8 (CP6–P6)] divided per question. Specifically, for question attractiveness: **a** bar graph shows O2Hb D values, and

b bar chart represents HHb D values of the interaction attractiveness × pain × channel. For question pain: **c** bar graph displays O2Hb D values, and **d** bar chart shows HHb D values of the interaction attractiveness × pain × channel. Bars represent ± 1 SE

modulated by cognitive empathy and top-down evaluation of empathic stimuli (Saxe and Kanwisher 2003); however, this right hemisphere activation seems to be related specifically to negative-valenced stimuli. In line with this, several studies previously highlighted that cortical right hemisphere hemodynamic activity seems to be more involved than the left side in processing negative cue (Balconi and Vanutelli 2016; Balconi et al. 2015; Balconi and Mazza 2010). The valence-specific hypothesis could be adopted to explain this result (Balconi and Pozzoli 2003; Junghöfer et al. 2001; Morita et al. 2001; Wedding and Stalans 1985). The cortical hemodynamic response is highly conditioned by the detection and evaluation of aversive negative cue and a mechanism of vigilance assigned to maintain a state of alertness when salient stimuli are encountered is likely to be located at the right brain hemisphere (Balconi et al. 2009; Balconi and Ferrari 2013).

Thus, according to previous research, it seems that, despite the painful condition, negative unattractive stimuli can trigger the activation of right brain TPJ areas involved in cognitive empathic response. Therefore, it seems possible to deduce that we feel more empathic towards an unattractive person regardless of whether he/she is in trouble.

The interpretation of a lower level of HHb as a marker of O2Hb presence is based on previous studies documenting that in some circumstances these two types of signals may respond in opposite directions during neural activation (Cui et al. 2010). Signal quality could be a possible explanation for discrepancies in findings. It is well known that O2Hb signals are more sensitive than HHb signals to changes in cerebral blood flow and have a higher signal-to-noise ratio (Strangman et al. 2002). Perhaps, for this reason, the majority of existing fNIRS studies have mainly reported results based on O2Hb signals rather than HHb signals. In line with the existing findings, we also opted for describing changes in neural responses in terms of HHb concentration as related to O2Hb variations. Nonetheless, future studies should deepen the functional significance of HHb decrease in complex neural networks including TPJ.

Therefore, we found a distinct lateralization effect for the cortical areas involved in rating attractiveness, with left IFG less active than the right hemispheric channels, specifically when asking participants to focus on the aesthetic judgment of face stimuli. While for the facial attractiveness features, a right hemisphere (specifically TPJ) enhanced activity was found for stimuli with a negative connotation (unattractive

stimuli compared to attractive stimuli). In contrast to our hypotheses, a left lateralization effect was not found for stimuli with a positive connotation per se (attractive and non-painful stimuli). Future studies will be necessary to explore if individuals are more prone to empathize with a person considered attractive within the empathy for pain context.

To the best of our knowledge, the present study is the first attempt to examine the influence of attractiveness on empathy for pain using fNIRS technique. At present, no significant interaction effects were found between face attractiveness and pain in O2Hb signal. In a previous fMRI study on physical attractiveness and sex as modulatory factors of empathic brain responses to pain, no significant activation was found when highly attractive faces were compared to less attractive ones within the pain condition, instead a significant interaction was found for attractiveness and the sex of the stimuli (Jankowiak-Siuda et al. 2015). Also, increased blood oxygenation level-dependent signals were found in the brain area related to empathy for pain (i.e., anterior insula and anterior cingulate cortex) when observing painful face stimuli with a different gradient of attractiveness, however, without clearly establishing if less or more attractive painful stimuli determined this activation (Jankowiak-Siuda et al. 2015). Despite these authors had the merit of suggesting attractiveness and sex of stimuli might constitute modulators of pain empathy, future studies are needed to better determine and clarify the relationship between face attractiveness and pain in O2Hb.

More generally, in the present study, differently from what expected, we did not find an effect for attractive stimulus and for the perception of painful stimuli per se, without an explicit request to evaluate face attractiveness or pain condition. Indeed, present findings may suggest that when aesthetic judgment is involved, pain stimuli might be attenuated and covert. While when the explicit request to evaluate pain is formulated, no specific differences were found between subjects and stimuli. Perhaps the absence of a significant effect might be due to the presence of the attractiveness condition that, indeed, smooth differences in pain and delete this effect. Aesthetic judgment and stimuli attractiveness might, therefore, trigger an empathic response that is independent of pain, going in the direction on the evaluation of attractive or non-attractive instead of a painful or non-painful condition.

This study is not without some limitations. Indeed, to ascertain the robustness of our neural findings and explore the other important subcortical and cortical correlates, future studies might consider using functional magnetic resonance imaging (fMRI), that is able to overcome fNIRS limited spatial resolution, either an fNIRS-EEG co-registration paradigm, to gather the neural response in real-time with higher temporal resolution. Moreover, self-report measures of empathy, such as the Balanced Emotional Empathy

Scale (Mehrabian and Epstein 1972) and the Interpersonal Reactivity Index (Davis 1980) should be integrated in future research to control if and how emotional and cognitive empathy traits might be related to the activation of the distinct neural correlates of aesthetic judgment (IFG) and face attractiveness (TPJ).

Code availability

Not applicable.

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Data availability The datasets generated for this study are available on request to the corresponding author.

Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest.

References

- Aharon I, Etcoff N, Ariely D et al (2001) Beautiful faces have variable reward value: fMRI and behavioral evidence. *Neuron* 32:537–551. [https://doi.org/10.1016/S0896-6273\(01\)00491-3](https://doi.org/10.1016/S0896-6273(01)00491-3)
- Allison T, Puce A, Mccarthy G (2000) Social perception from visual cues: role of the STS region. *Trends Cogn Sci* 4:267–278
- Balconi M, Ferrari C (2013) Repeated transcranial magnetic stimulation on dorsolateral prefrontal cortex improves performance in emotional memory retrieval as a function of level of anxiety and stimulus valence. *Psychiatry Clin Neurosci* 67:210–218. <https://doi.org/10.1111/pcn.12041>
- Balconi M, Mazza G (2010) Lateralisation effect in comprehension of emotional facial expression: a comparison between EEG alpha band power and behavioural inhibition (BIS) and activation (BAS) systems. *Laterality Asymmetries Body. Brain Cogn* 15:361–384. <https://doi.org/10.1080/13576500902886056>
- Balconi M, Pozzoli U (2003) Face-selective processing and the effect of pleasant and unpleasant emotional expressions on ERP correlates. *Int J Psychophysiol* 49:67–74. [https://doi.org/10.1016/S0167-8760\(03\)00081-3](https://doi.org/10.1016/S0167-8760(03)00081-3)
- Balconi M, Vanutelli ME (2016) Hemodynamic (fNIRS) and EEG (N200) correlates of emotional inter-species interactions modulated by visual and auditory stimulation. *Sci Rep*. <https://doi.org/10.1038/srep23083>
- Balconi M, Brambilla E, Falbo L (2009) BIS/BAS, cortical oscillations and coherence in response to emotional cues. *Brain Res Bull* 80:151–157. <https://doi.org/10.1016/j.brainresbull.2009.07.001>
- Balconi M, Grippa E, Vanutelli ME (2015) What hemodynamic (fNIRS), electrophysiological (EEG) and autonomic integrated measures can tell us about emotional processing. *Brain Cogn* 95:67–76. <https://doi.org/10.1016/j.bandc.2015.02.001>
- Batson D (2014) *The altruism question. Toward a social-psychological answer*. Psychology Press, New York
- Borod JC, Cicero BA, Obler LK et al (1998) Right hemisphere emotional perception: evidence across

- multiple channels. *Neuropsychology* 12:446–458. <https://doi.org/10.1037//0894-4105.12.3.446>
- Botvinick M, Jha AP, Bylsma LM et al (2005) Viewing facial expressions of pain engages cortical areas involved in the direct experience of pain. *Neuroimage* 25:312–319. <https://doi.org/10.1016/j.neuroimage.2004.11.043>
- Calvo-Merino B, Urgesi C, Orgs G et al (2010) Extrastriate body area underlies aesthetic evaluation of body stimuli. *Exp Brain Res* 204:447–456. <https://doi.org/10.1007/s00221-010-2283-6>
- Chatterjee A, Thomas A, Smith SE, Aguirre GK (2009) The neural response to facial attractiveness. *Neuropsychology* 23:135–143. <https://doi.org/10.1037/a0014430>
- Craig K, Prkachin K, Grunau R (2001) The facial expression of pain. In: Turk D, Melzack R (eds) *Handbook of pain assessment*, 2nd edn. Guilford Press, New York, pp 153–169
- Cui X, Bray S, Reiss AL (2010) Functional near infrared spectroscopy (fNIRS) signal improvement based on negative correlation between oxygenated and deoxygenated hemoglobin dynamics. *Neuroimage* 49:3039–3046. <https://doi.org/10.1016/j.neuroimage.2009.11.050>
- Davis MH (1980) A multidimensional approach to individual differences in empathy. *J Pers Soc Psychol*. <https://doi.org/10.1037/0022-3514.44.1.113>
- de Waal FBM (2008) Putting the altruism back into altruism: the evolution of empathy. *Annu Rev Psychol* 59:279–300. <https://doi.org/10.1146/annurev.psych.59.103006.093625>
- Dixson AF, Halliwell G, East R et al (2003) Masculine somatotype and hirsuteness as determinants of sexual attractiveness to women. *Arch Sex Behav* 32:29–39. <https://doi.org/10.1023/A:1021889228469>
- Fan Y, Han S (2008) Temporal dynamic of neural mechanisms involved in empathy for pain: an event-related brain potential study. *Neuropsychologia* 46:160–173. <https://doi.org/10.1016/j.neuropsychologia.2007.07.023>
- Frith U, Frith CD (2003) Development and neurophysiology of mentalizing. *Philos Trans Biol Sci*. <https://doi.org/10.1098/rstb.2002.1218>
- Fu G, Mondloch C, Ding XP et al (2014) The neural correlates of the face attractiveness aftereffect: a functional near-infrared spectroscopy (fNIRS) study. *Neuroimage* 85:1–7. <https://doi.org/10.1038/jid.2014.371>
- Fusar-poli P, Placentino A, Carletti F et al (2009) Laterality effect on emotional faces processing: ALE meta-analysis of evidence. *Neurosci Lett* 452:262–267. <https://doi.org/10.1016/j.neulet.2009.01.065>
- Greccucci A, Giorgetta C, Bonini N, Sanfey AG (2013) Reappraising social emotions: the role of inferior frontal gyrus, temporo-parietal junction and insula in interpersonal emotion regulation. *Front Hum Neurosci* 7:1–12. <https://doi.org/10.3389/fnhum.2013.00523>
- Gu X, Han S (2007) Attention and reality constraints on the neural processes of empathy for pain. *Neuroimage* 36:256–267. <https://doi.org/10.1016/j.neuroimage.2007.02.025>
- Han S, Fan Y, Xu X et al (2009) Empathic neural responses to others' pain are modulated by emotional contexts. *Hum Brain Mapp* 30:3227–3237. <https://doi.org/10.1002/hbm.20742>
- Haxby JV, Hoffman EA, Gobbini MI (2000) The distributed human neural system for face perception. *Trends Cogn Sci* 4:223–233. [https://doi.org/10.1016/S1364-6613\(00\)01482-0](https://doi.org/10.1016/S1364-6613(00)01482-0)
- Hoaglin DC, Iglewicz B, Hoaglin DC, Iglewicz B (1987) Fine-tuning some resistant rules for outlier labeling. *J Am Stat Assoc* 82:1147–1149
- Hornstein HA (1972) Promotive tension: the basis of prosocial behavior from a lewinian perspective. *J Soc Issues* 28:191–218. <https://doi.org/10.1111/j.1540-4560.1972.tb00039.x>
- Ishai A (2007) Sex, beauty and the orbitofrontal cortex. *Int J Psychophysiol* 63:181–185. <https://doi.org/10.1016/j.ijpsycho.2006.03.010>
- Ishizu T, Zeki S (2013) The brain's specialized systems for aesthetic and perceptual judgment. *Eur J Neurosci* 37:1413–1420. <https://doi.org/10.1111/ejn.12135>
- Jackson PL, Meltzoff AN, Decety J (2005) How do we perceive the pain of others? A window into the neural processes involved in empathy. *Neuroimage* 24:771–779. <https://doi.org/10.1016/j.neuroimage.2004.09.006>
- Jankowiak-Siuda K, Rymarczyk K, Żurawski Ł et al (2015) Physical attractiveness and sex as modulatory factors of empathic brain responses to pain. *Front Behav Neurosci* 9:1–11. <https://doi.org/10.3389/fnbeh.2015.00236>
- Johnson JD, Simmons CH, Jordav A et al (2002) Rodney King and O.J. Revisited: the impact of race and defendant empathy induction on judicial decisions. *J Appl Soc Psychol* 32:1208–1223. <https://doi.org/10.1111/j.1559-1816.2002.tb01432.x>
- Junghöfer M, Bradley MM, Elbert TR, Lang PJ (2001) Fleeting images: a new look at early emotion discrimination. *Psychophysiology* 38:175–178. <https://doi.org/10.1017/S0048577201000762>
- Kirsch LP, Urgesi C, Cross ES (2016) Neuroscience and biobehavioral reviews shaping and reshaping the aesthetic brain: emerging perspectives on the neurobiology of embodied aesthetics. *Neurosci Biobehav Rev* 62:56–68. <https://doi.org/10.1016/j.neubiorev.2015.12.005>
- Lamm C, Singer T (2010) The role of anterior insular cortex in social emotions. *Brain Struct Funct* 214:579–591. <https://doi.org/10.1007/s00429-010-0251-3>
- Liang X, Zebrowitz LA, Zhang Y (2010) Neural activation in the “reward circuit” shows a nonlinear response to facial attractiveness. *Soc Neurosci* 5:320–334. <https://doi.org/10.1080/17470911003619916>
- Ma DS, Correll J, Wittenbrink B (2015) The Chicago face database: a free stimulus set of faces and norming data. *Behav Res Methods* 47:1122–1135. <https://doi.org/10.3758/s13428-014-0532-5>
- Martin-Loeches M, Hernandez-Tamames JA, Martin A, Urrutia M (2014) Beauty and ugliness in the bodies and faces of others: an fMRI study of person esthetic judgement. *Neuroscience* 277:486–497
- Mehrabian A, Blum JS (1997) Physical appearance, attractiveness, and the mediating role of emotions. *Curr Psychol* 16:20–42. <https://doi.org/10.4324/9781351309561-1>
- Mehrabian A, Epstein N (1972) A measure of emotional empathy. *J Pers* 40:525–543
- Morita Y, Morita K, Yamamoto M et al (2001) Effects of facial affect recognition on the auditory P300 in healthy subjects. *Neurosci Res* 41:89–95. [https://doi.org/10.1016/S0168-0102\(01\)00248-6](https://doi.org/10.1016/S0168-0102(01)00248-6)
- O'Doherty J, Winston J, Critchley H et al (2003) Beauty in a smile: the role of medial orbitofrontal cortex in facial attractiveness. *Neuropsychologia* 41:147–155. [https://doi.org/10.1016/S0028-3932\(02\)00145-8](https://doi.org/10.1016/S0028-3932(02)00145-8)
- Preston SD, de Waal FBM (2002) Empathy: its ultimate and proximate bases. *Behav Brain Sci* 25:1–72. <https://doi.org/10.1017/S0140525X02000018>
- Rhodes GI, Jeffery L, Watson TL et al (2003) Face attractiveness after-effects: fitting the mind to the world. *Psychol Sci* 14:558–566. <https://doi.org/10.1167/3.9.298>
- Saarela MV, Hlushchuk Y, Williams ACDC et al (2007) The compassionate brain: humans detect intensity of pain from another's face. *Cereb Cortex* 17:230–237. <https://doi.org/10.1093/cercor/bhj141>
- Saxe R, Kanwisher N (2003) People thinking about thinking people: the role of the temporo-parietal junction in “theory of mind”. *Neuroimage* 19:1835–1842. [https://doi.org/10.1016/S1053-8119\(03\)00230-1](https://doi.org/10.1016/S1053-8119(03)00230-1)
- Schwartz GE, Davidson RJ, Maer F (1975) Right hemisphere lateralization for emotion in the human brain: Interactions with cognition. *Science* (–80) 190:286–288. <https://doi.org/10.1126/science.1179210>

- Shamay-tsoory S (2015) The neuropsychology of empathy: evidence from lesion studies. *Rev Neuropsychol* 7:237–243. <https://doi.org/10.1684/nrp.2015.0356>
- Sheng F, Han S (2012) Manipulations of cognitive strategies and intergroup relationships reduce the racial bias in empathic neural responses. *Neuroimage* 61:786–797. <https://doi.org/10.1016/j.neuroimage.2012.04.028>
- Simon D, Craig KD, Miltner WHR, Rainville P (2006) Brain responses to dynamic facial expressions of pain. *Pain* 126:309–318. <https://doi.org/10.1016/j.pain.2006.08.033>
- Singer T, Seymour B, O’Doherty J et al (2004) Empathy for pain involves the affective but not sensory components of pain. *Science* 80(303):1157–1162. <https://doi.org/10.1126/science.1093535>
- Singer T, Seymour B, O’Doherty JP et al (2006) Empathic neural responses are modulated by the perceived fairness of others. *Nature* 439:466–469. <https://doi.org/10.1038/nature04271>
- Van Overwalle F (2009) Social cognition and the brain: a meta-analysis. *Hum Brain Mapp* 30:829–858. <https://doi.org/10.1002/hbm.20547>
- Wedding D, Stalans L (1985) Hemispheric differences in the perception of positive and negative faces. *Int J Neurosci* 27:277–281
- Xu X, Zuo X, Wang X, Han S (2009) Do you feel my pain? Racial group membership modulates empathic neural responses. *J Neurosci* 29:8525–8529. <https://doi.org/10.1523/JNEUROSCI.2418-09.2009>

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