The role of spatial frequency information in the decoding of facial expressions of pain: a novel hybrid task

Shan Wang[a, b *], Christopher Eccleston[a, c], Edmund Keogh[a, b]

a. Centre for Pain Research, University of Bath
b. Department of Psychology, University of Bath
c. Department of Experimental-Clinical and Health Psychology, Ghent University, Belgium

* Correspondence: Shan Wang, Department of Psychology & Centre for Pain Research, University of Bath, Claverton Down, Bath, BA2 7AY, United Kingdom; E-mail: s.wang@brookes.ac.uk; URL: http://www.bath.ac.uk/pain/

Type of manuscript: Research paper

Number of pages (with references): 25

Number of Tables: 6

Number of Figures: 3

Running head: Spatial frequency information and pain expression decoding

Disclosure statement: Shan Wang received a PhD scholarship from the University of Bath to conduct this research.

Conflict of interest: None

Abstract

Spatial frequency (SF) information contributes to the recognition of facial expressions, including pain. Low-SF encodes facial configuration and structure and often dominates over high-SF information, which encodes fine details in facial features. This low-SF preference has not been investigated within the context of pain. In this study we investigated whether perpetual preference differences exist for low- and high-SF pain information. A novel hybrid expression paradigm was used, in which two different expressions, one containing low-SF information and the other high-SF information, were combined in a facial hybrid. Participants are instructed to identify the core expression contained within the hybrid, allowing for the measurement of SF information preference. Three experiments were conducted (46 participants in each) that varied the expressions within the hybrid faces: respectively pain-neutral, pain-fear, and pain-happiness. In order to measure the temporal aspects of image processing, each hybrid image was presented for 33, 67, 150 and 300 ms. As expected, identification of pain and other expressions was dominated by low-SF information across the three experiments. The low-SF preference was largest when the presentation of hybrid faces was brief, and reduced as the presentation duration increased. A sex difference was also found in Experiment 1. For women, the low-SF preference was dampened by high-SF pain information, when viewing low-SF neutral expressions. These results not only confirm the role that SF information has in the recognition of pain in facial expressions, but suggests that in some situations there may be sex differences in how pain is communicated.

Key words: Pain, Facial expression, Spatial frequency, Hybrid, Presentation duration

1 Introduction

Pain is a subjective experience, but also occurs within a social context. Effective pain communication strategies are needed to elicit help and alert others to potential threats [48,67,68]. Mechanisms have evolved, including unique nonverbal facial expressions, to enable observers to detect pain in others [9,18,27,51,58,65]. However, beyond basic description it is less clear *how* such expressions are processed, and what information makes the recognition of pain possible.

One approach is to consider the different sources of information contained within the face. From a perceptual perspective, the recognition of objects, including faces, can be achieved by analysing the spatial frequency (SF) information contained within them [7,12,59,65]. High-SF information encodes fine-detailed facial features and abrupt edges, and is used when faces are viewed close up [7,54,59]. Low-SF encodes large-scale facial configuration and coarse structures, and is used when viewing objects at distance or in the periphery. Coarse low-SF information projects to the amygdala [37,66], which is linked to processing social threatening cues [54] and suffering in others [40,59,65], and also seems to be processed faster than high SF information [23,39,64]. This has led to the coarse-to-fine processing hypothesis, in which a coarse description of a face is first formed, followed by the integration of fine details, in order to produce successful recognition and understanding of facial expressions [23].

Applying this hypothesis to pain, we might expect efficient pain expression decoding to be based on the preferential processing of low-SF information. It would be adaptive to quickly process the gist of an expression associated with harm, especially in restricted visual environments, in order to act quickly. However, only indirect support exists, since low-SF and high-SF pain faces have typically been presented separately, and not in direct competition [52,65]. This current study was therefore designed to test the coarse-to-fine hypothesis within the context of pain, and further our understanding about how people interpret and preferentially select information to decode painful expressions.

We utilized a novel hybrid expression paradigm [55] that concurrently presents low- and high-SF information from different expressions (e.g. low-SF pain with high-SF neutral), with choice responses reflecting information preferences during decoding. Related work with emotional expression hybrids indicates a preference towards coarse low-SF information [55], although this can depend on the expression combination used, e.g. happiness is more likely to be perceived in low-SF than anger [34]. Three experiments were planned, in which pain was paired within different hybrid expression combinations: pain-neutral, pain-fear, pain-happiness. We hypothesised that low-SF information would be more salient for pain expressions, and at a similar level to emotional expressions. We also varied stimulus presentation durations, with an expectation that the low-SF preference would be strongest when hybrids were presented at relatively short durations. Finally, given that there are sex differences in both recognition of facial expressions [19,20,30] and perception of pain [28,29,66], we consider male-female variation. We predicted that females would be more susceptible to the influence of expressions presented through high-SF, and at faster onset durations.

2 Experiment 1: Pain-neutral hybrids

In Experiment 1, we examined whether low- or high-SF pain expressions would be preferentially perceived when combined with neutral expressions in hybrid faces.

2.1 Methods

2.1.1 Participants

Forty-three healthy adult participants (23 females and 20 males) were recruited from the University of Bath. The sample had a mean age of 22.07 (*SD* = 6.14). All participants had normal or correct to normal vision and reported being pain-free and free from any psychiatric or neurological conditions.

2.1.2 Design

Participants completed an expression recognition task that employed a mixed-groups design. The within-groups variables were presentation duration (33 vs. 67 vs. 150 vs. 300 ms) and low-SF information (pain vs. neutral). There were two types of hybrid face combination in this experiment (i.e. <u>low-SF pain</u> & high-SF neutral, and <u>low-SF neutral</u> & high-SF pain), the low-SF expressions of pain and neutral corresponded to the two types of hybrid face, respectively. A between-groups variable of participant sex (male vs. female) was also included. The dependent variable was preference towards low-SF expression information in the hybrid faces.

2.1.3 Stimuli

Hybrid faces are produced by merging one low-SF and one high-SF face, each showing a different expression [55]. For an example of a hybrid face image, please refer to Figure 1. The hybrid faces make the direct competition possible by containing two independent expressions in low-SF and high-SF separately at the same time. In an expression recognition task, the selected expression accordingly probes which information is preferentially perceived. For example, one image could be composed of a low-SF component showing pain, and a high-SF neutral component, whereas a second image could be reversed, i.e. a low-SF neutral expression paired with high-SF pain. If the first image is perceived as showing a pain expression, the low-SF information is preferentially perceived; whereas if pain is chosen in the second image, this would suggest a preference for high-SF information.

We utilised the same face expression stimuli as reported in our previous study on SF information in pain and emotion recognition [65]. The original face images derived from the STOIC database, which comprised five male and five female actors, displayed a range of validated facial expressions, including pain [53]. For the purpose of this experiment, the low-SF and high-SF filtered face images of pain and neutral expressions were used to produce the hybrid face stimuli. The SF filtering of original face images was described earlier [65]. The hybrid faces were produced by merging a low-SF face and a high-SF face, each showing an expression of pain or neutral. Thus, two types of hybrid faces were produced – low-SF pain & high-SF neutral and low-SF neutral & high-SF pain. In each hybrid face, the two expressions were shown by the same actor, in order to eliminate potential effects of actors' sex or identity on the perception of expressions. As each expression was presented by 10 models (five females and five males) in the original stimulus set, a total of 20 hybrid faces were produced and used as stimuli in this experiment (i.e. two hybrid combinations × 10 models). The hybrid stimuli were produced using MATLAB 2013.

------ Insert Figure 1 around here ------

2.1.4 Task

The task was designed and controlled using E-Prime professional 2.0. Stimuli were displayed in their original size of 7.62 × 7.62 cm on a 19" LCD screen with the resolution of 1280 × 1024 pixels and a refresh rate of 60 Hz. Participants' viewing distance was approximately 60 cm with a visual angle of 3.63°. This task consisted of 4 sessions, with each session assigning a presentation duration from a selection of 33, 67, 150, and 300 ms. The presentation durations of 33 and 150 ms were comparable to that used in the literature investigating the temporal features of SF preference for natural scene perception [56]. The presentation duration of 67 ms was close to that used in studies of emotional facial expressions [55], where a general low-SF preference was found. The fixed presentation duration (i.e. 300 ms) used in our previous study [65] was also included as the longest duration. This is because, under natural viewing conditions, the average eye gaze fixation is approximately 300 ms [13,24]. Thus, in this experiment, the presentation durations allowed no more than one fixation on each hybrid stimulus, which ensures that the responded expression was preferentially perceived rather than freely selected between the two [21,35].

In each session, participants completed 100 trials, with each hybrid face image (20 hybrid stimulus images in total) appearing five times. In each trial, participants were shown a fixation cross at the centre of the screen for 500 ms followed by a hybrid stimulus. The hybrid stimulus was presented one at a time for the given presentation duration of the session and randomly jittered over ±0.3° to prevent participants from fixating on a particular feature. Participants were asked to recognise the expression of the face by pressing the corresponding button on the response box as quickly and as accurately as possible. The buttons were labelled with *pain* and *neutral*.

There was not a correct or incorrect answer in this experiment. The responded expression probes which type of SF information was preferentially perceived by participants. For example, when a hybrid stimulus of low-SF pain & high-SF neutral was shown, a response of *pain* demonstrated that the low-SF information was perceived in preference to the high-SF information, in which a neutral expression was shown in this case. A response could be made within 2000 ms of the onset of the stimulus, after which the trial terminated and moved onto the next trial with or without a response. A 2000-millisecond limit is recommended for studies of this type as a reasonable cut-off to minimise the effect of RT outliers [49]. It is also considered long enough to allow participants to make manual responses after conscious processing of a visual stimulus [36,61,62]. A blank screen was displayed for 500 ms prior to the next trial to reduce any adaptation effect, and then the next trial began with the fixation cross.

2.1.5 Procedure

Ethical approval was granted by the Department of Psychology Ethics Committee (Ref. 13-161) and the Department of Health Ethics Committee (Ref. EP 13/14 33a) of the University of Bath for all three experiments. Informed consent was obtained from all participants prior to participation. Participants, who were first-year psychology students, were awarded one credit unit for participation, and all other participants were given £5 in return.

The hybrid stimuli within each session were shown in a random order, and the order of sessions was counterbalanced across participants. Each participant was required to complete the four sessions with a break scheduled between each one. A practice session of 20 trials preceded the main task. The hybrid stimuli in practice session were randomly selected from the 20 hybrid stimulus images for each participant.

2.1.6 Data analysis

One-sample binomial tests (two-tailed, test proportion 50%) were firstly applied to examine whether expression recognition was driven by low-SF or high-SF information. After this, the effects of presentation duration, low-SF expression type, and participants' sex on the SF information preference were examined. The dependent variable was the preference towards low-SF expression information. Following the method used by Schyns and Oliva [55], a preference score was calculated by subtracting the number of high-SF responses from low-SF responses.

Data of preference towards low-SF were entered into a 4 × 2 × 2 (Presentation Duration [33, 67, 150, 300 ms] × Low-SF Expression [pain, neutral] × Participant Sex [female, male]) mixed-groups ANOVA. Simple effects analyses were applied when significant interactions were found. *Post hoc* analyses with Bonferroni-type correction were conducted when required, and the corrected cut-off point for each analysis was calculated following 0.05/the number of comparison rule (e.g. when there are three comparisons, the corrected cut-off point is 0.05/3 = 0.0167). The significance levels after Bonferroni-type adjustment ($p < .05$, $p < .01$, or $p < .001$) and the effect sizes (Cohen's *d*) are reported for each comparison.

2.2 Results

2.2.1 Data screening

Data[1] were firstly screened to remove trials with responses made within 200 ms or after 2000 ms (1.97% of all trials). The preference score was then calculated for each participant. No outlier was found, with *z*-scores lying within an acceptable range, i.e. between -3.29 and 3.29 [60]. The data were approximately normally distributed, with acceptable *z*-scores of skewness and kurtosis between -3.29 and 3.29 [8], and were approximately homogeneous (all Levene's *p*s > .05). For factors where sphericity could not be assumed, *F*-ratios with adjusted degrees of freedom and *p*-values are reported.

2.2.2 Analysis of SF preference

One-sample binomial tests (two-tailed; test proportion = 50%) revealed that low-SF information in expressions were preferentially perceived compared with high-SF information,

[1] In this experiment, participants' response time was recorded for the purpose of data screening only and not included in the analysis. This is because the task was designated to examine a preference, where extremely small numbers of responses were expected in some conditions. However, the number of responses (< 20) was not adequate to produce reliable mean response time in these conditions.

and that this was found in both female and male participants. These results are presented in Table 1.

------ Insert Table 1 & 2 here ------

Means and SDs of the preference towards low-SF are presented in Table 2. Statistical analysis revealed a significant main effect of presentation duration, F (2.83, 115.93) = 15.49, $p < .001$, $\eta^2_p = .27$. Greater low-SF preference was found for hybrid faces when presented for 33 ms, compared to those presented for 67, 150, and 300 ms (all *p*s < .05, Cohen's *d*s > 0.52). No other differences were significant (all *p*s > .10). The main effect of low-SF expression type was not significant, F (1, 41) < 0.01, $p = 1.00$.

In terms of sex differences, the main effect of participant sex was not significant, F (1, 41) = 2.60, $p = .12$. However, a significant interaction was found between low-SF expression type and participant sex (Figure 2), F (1, 41) = 5.17, $p < .05$, $\eta^2_p = .11$. Simple effects analysis revealed significant sex difference in the preference for low-SF neutral expressions, F (1, 41) = 7.69, $p < .01$, $\eta^2_p = .16$. Males showed a greater preference to low-SF neutral expressions than females (Cohen's $d = 0.85$). Although there was a general low-SF preference, this result suggests that males were less likely to perceive the complementary part of high-SF pain than females. The sex difference for low-SF information was not significant when expressions were pain-related, F (1, 41) < 0.01, $p = .96$.

------ Insert Figure 2 around here ------

None of the other interactions were significant, all *F*s < 2.03, *p*s > .11.

2.3 Discussion

Experiment 1 found that coarse low-SF information is preferred over the fine-detailed high-SF information for decoding of both pain and neutral expressions. This low-SF preference is modified by the presentation duration – the preference towards low-SF expressions was largest when hybrid faces presented briefly and reduced as the presentation duration increased.

Although there was a general low-SF preference, there was also a sex difference in the way that high-SF pain information modifies this effect. Specifically, we found that when the low-SF information contains neutral expressions, this preference is reduced when the competing high-SF information is pain-related. However, this pain-related effect was only found in females. This suggests that females may be more sensitive to the fine details associated with pain in others.

It is of course possible that the effects found in Experiment 1 represent a general emotionality preference rather than a specific effect associated with pain. We, therefore, decided to conduct two additional experiments, with different hybrid expression pairings. We chose to pair pain with fear and happiness, as we have previously showed that these two expressions are respectively perceived to be very similar, and very different, from pain [65]. In Experiment 2, we examined whether pain expressions presented with either low-SF or high-SF information would be preferentially perceived when combined with fear expressions in the hybrid faces. Fear expressions are perceived to be similar to pain in terms of both valence and arousal levels [65], and so we predicted that low-SF information would elicit a general perceptual preference. We also expected this effect to be attenuated in females when the high-SF information was related to pain.

3 Experiment 2: Pain-fear hybrids

3.1 Methods

3.1.1 Design

The same mix-groups design was used as in Experiment 1. The only one difference was that the hybrid faces combined expressions of pain and fear. The within-groups variables were presentation duration (33 vs. 67 vs. 150 vs. 300 ms) and low-SF expression (pain vs. fear). The between-groups variable was participant's sex (male vs. female). The dependent variable was preference towards low-SF expressions.

3.1.2 Participants

An additional forty-three healthy adult participants (23 females and 20 males) were recruited to complete the Experiment 2. The sample had a mean age of 25.74 (*SD* = 5.58). The exclusion criteria for recruitment and the payment information were the same as in Experiment 1.

3.1.3 Stimuli & Task

The same expression recognition task was used as in Experiment 1, with the only difference being that participants were asked to recognise whether the face stimulus was showing a pain or a fear expression. The hybrid stimuli were produced using the same method as described in Experiment 1, resulting in 20 hybrid faces: low-SF pain & high-SF fear and low-SF fear & high-SF pain, each presented by 10 models.

3.1.4 Data analysis

The same data analysis methods were used as in Experiment 1.

3.2 Results

3.2.1 Data screening

Data were screened to remove trials with responses made within 200 ms or after 2000 ms (2.47% of all trials). The score of preference was calculated for each participant by subtracting the number of high-SF responses from low-SF responses. No outliers were found. The data were normally distributed and were approximately homogeneous.

3.2.2 Analysis of SF preference

One-sample binomial tests (two-tailed; test proportion = 50%) revealed that most expressions were perceived in terms of the low-SF information. However, there was one exception: for hybrid faces containing low-SF fear & high-SF pain, female participants did not show significant low-SF (53%) preference over high-SF (47%) when presented for 300 ms. The results are presented in Table 3.

------ Insert Table 3 & 4 here ------

Means and SDs of the score of preference in each condition are presented in Table 4. Statistical analysis revealed a significant main effect of presenting duration, F (3, 123) = 14.86, $p < .001$, $\eta^2_p = .27$. As before, participants exhibited the greatest low-SF preference with presenting time of 33 ms than 67, 150, and 300 ms (all *p*s < .01, Cohen's *d*s > 0.53); and greater preference was also found between 67 ms and 300 ms ($p < .05$, Cohen's $d = 0.49$).

The main effect of expression was not significant, F (1, 41) = 0.22, $p = .64$. No significant sex difference was found, F (1, 41) = 0.56, $p = .46$. None of the interactions was significant, all *F*s < 0.86, *p*s > .46.

3.3 Discussion

Similar to Experiment 1, Experiment 2 found a preference towards low-SF in the detection of both pain and fearful information from facial expressions, and again the size of the preference was reduced as the presentation duration increased. In addition, women seemed to detect the high-SF pain information as often as the competing low-SF fear, when the hybrid faces were presented at the longest presentation duration (i.e. 300 ms). However, this effect was not observed for men.

Experiment 3 examined whether pain expressions presented in either low-SF or high-SF information would be preferentially perceived when combined with a very different expression, namely happiness.

4 Experiment 3: Pain-happiness hybrids

4.1 Methods

4.1.1 Design

The same mixed-groups design was used as described in Experiments 1 and 2. The only difference was the hybrid faces combined pain and happiness expressions.

4.1.2 Participants

An additional forty-three healthy adult participants (23 females and 20 males) were recruited into Experiment 3. The sample had a mean age of 23.30 (*SD* = 4.71).

4.1.3 Stimuli & task

In this experiment, stimuli comprised of two hybrid combinations: <u>low-SF pain & high-SF happiness</u> and <u>low-SF happiness & high-SF pain</u>. Participants were asked to indicate whether the face stimulus displayed a pain expression or a happiness expression.

4.1.4 Data analysis

The same data analysis methods were used as in the previous two experiments.

4.2 Results

4.2.1 Data screening

One female participant was excluded from further analysis due to missing responses. Data were screened to remove trials with responses faster than 200 ms or slower than 2000 ms (2.35% of all trials). No outliers were found in preference scores, and the data were normally distributed and homogeneous. Final data for this experiment were from a sample of 42 participants (22 females and 20 males).

4.2.2 Analysis of SF preference

One-sample binomial tests (two-tailed; test proportion = 50%) revealed that low-SF expression information was perceived in preference to those high-SF information in all conditions, by both female and male participants. The results are presented in Table 5.

------ Insert Table 5 & 6 here ------

Means and SDs of the score of preference towards low-SF expressions in each condition are presented in Table 6. Statistical analysis revealed a significant main effect of presentation duration, F (3, 120) = 21.22, $p < .001$, $\eta^2_p = .35$. As before, the low-SF preference was greater when hybrid faces were presented for 33 ms than 67, 150, and 300 ms (all ps < .05, Cohen's ds > 0.45); and greater low-SF preference for 67 ms than 150 and 300 ms (both ps < .01, Cohen's ds > 0.55).

The main effect of low-SF expression was significant, F (1, 40) = 20.49, $p < .001$, $\eta^2_p = .34$. This indicated a greater low-SF preference when the low-SF expression depicted happiness compared to pain ($p < .001$, Cohen's d = 0.71).

A significant interaction was also found between presentation duration and expression hybrid type (Figure 3), F (2.46, 98.34) = 4.05, $p < .05$, $\eta^2_p = .09$. Simple effects analysis revealed that the effect of presentation duration was not significant when low-SF expression depicted pain, F (3, 38) = 1.21, $p = .32$. However, a significant effect of presentation duration was found when low-SF information depicted happiness, F (3, 38) = 11.91, $p < .001$, $\eta^2_p = .49$. Greater low-SF preference for happiness was found at 33 and 67 ms, when compared to 150 and 300 ms (all *p*s < .01, Cohen's *d*s > 0.54). Simple effects analysis also revealed a significant effect of expression type when presentation durations were at 33, 67, and 300 ms (all *F*s > 6.28, *p*s < .05, η^2_ps > .13). A greater low-SF preference was found when the low-SF expression was happiness compared to pain (all *p*s < .05, Cohen's *d*s > 0.39). No significant difference was found when the presentation duration was set at 150 ms ($p = .06$).

------ Insert Figure 3 around here ------

No significant sex difference was found, F (1, 40) = 0.61, $p = .44$. None of the other interactions were significant, all *F*s < 1.50, *p*s > .22.

4.3 Discussion

While the results of Experiment 3 suggested a preference towards low-SF information for both pain and happiness expressions, a greater low-SF preference was elicited by happiness compared to pain. Interestingly, when the competing high-SF was showing happiness, the preference towards low-SF pain was no longer modified by the presentation duration. More interestingly, these findings were observed for both male and female participants, suggesting no sex difference.

5 General discussion

This study confirmed that the different perceptual information contained within facial expressions is preferentially selected when decoding pain. Using a novel hybrid expression task, conflicting low- and high-SF information was combined to test whether perceptual preferences for pain were more likely to be driven by low-SF information. Not only was this low SF-preference confirmed, but a similar pattern was found for the core emotions of fear and happiness, as well as neutral expressions.

This is first time that a low-SF perceptual preference has been found for pain expressions, and moves away from simple description to show how observers preferentially select, and subsequently, interpret information contained in facial expressions. These results are consistent with previous investigations into the recognition of emotional expressions using hybrid images [34,55], as well as broader conceptual approaches to perception that suggest coarse (low-SF) information plays an important role at an early stage of image decoding, and/or when environments are ambiguous or of low quality (e.g. low light, at a distance) [1,26,56]. Since not all perceptual environments are clear and unambiguous, it is evolutionarily adaptive for low-SF information playing an advantageous role in expression recognition, including pain, under perceptually competitive or challenging conditions. If low-SF information can still be used to quickly generate the gist of the expression or object being viewed, this would allow the observer to efficiently consider the possible actions and intensions of others, and act accordingly. Only when expressions are presented with less ambiguity or there is a need for more sophisticated processing, fine-detailed information contained within high-SF is allowed to enter perceptual awareness.

These results directly build upon the work reported by Wang et al. [65], by confirming the relevance of perceptual information when observing expressions of pain. Interestingly, the original study demonstrated that whilst both low-SF and high-SF information was used for decoding expressions of pain, low-SF information was particularly relevant for pain expressions [65]. However, the current study found that low-SF dominates for all expressions considered. Whilst this might seem contradictory, there was an important difference in the tasks used. Wang et al. [67] presented images in either low- or high-SF information and asked to identify the expression, whereas in the current study, these alternative types of perceptual information were placed in direct competition with each other, and a forced choice response required. What this suggests is that while low- and high-SF can be used to identity pain, when in visually competitive and/or ambiguous situations low-SF information dominates perceptual choices. That this low-SF information preference was not limited to pain in the current study suggests a general processing preference for low-SF information when conflicting information is presented.

There was, however, one notable situation where high-SF information about pain seemed to reduce this general low-SF preference. Amongst women, when low-SF expressions were either neutral or related to fear with a longer presentation duration (300 ms), then high-SF pain information seemed to dampen down, or reduce, this low-SF preference effect. Though there was still a low-SF preference, the high-SF pain features seemed to 'break through' and enter women's visual perception in competitive situations (i.e. hybrid faces). This is particularly interesting, as it suggests that detailed information within pain-related expressions may in some circumstances enter perceptual awareness more in females than males. It may be related to females' sensitivity to pain signals [28,29], which lead to a greater awareness of pain in others also (e.g. greater pain-related empathy). This suggests that there may be sex differences in pain recognition, which have generally not been reported in previous research. This could again be due to the hybrid paradigm used here, which goes beyond simple expression recognition, and examines perceptual preferences under ambiguous and competitive visual conditions.

Although the fine details of pain expression might dampen down the low-SF preference in women, this effect was limited in Experiment 2 to slower presentation durations, and not found at all in Experiment 3, where the hybrid expressions contained happiness. Interestingly, in Experiment 3, we found a greater low-SF preference elicited by happiness when compared to pain expressions – an expression difference that was not found for either neutral (Experiment 1) or fear (Experiment 2). Previous research has also tended to find a dominance for happiness-related expressions [6,34]. For example, Laprevote et al. [34] found that while the perception of expression was dominated by the low-SF component in hybrid faces, a greater low-SF preference was found for happiness than anger expressions [34]. This suggests that, when compared with a negative expression (e.g. pain or anger), happiness was preferentially perceived in low-SF information.

We also considered whether the preference of SF information would be modified by the presentation duration of hybrid faces. Across all three experiments, participants' perceptual preference towards low-SF information was most prominent during the faster presentation trials and somewhat reduced as the presentation durations increased. However, as with the sex-related effect reported above, the one exception to this was when examining the pain-happiness hybrids in Experiment 3. Here, when pain was in the low-SF component and happiness the high-SF, the preference towards low-SF pain was not affected by the presentation duration. The increased presentation duration did not make the high-SF happiness more visible when the paired expression was pain, perhaps because happiness captures perception at even early phases of object recognition. Temporal features have been examined in other studies of hybrid facial expressions [10,11,55], suggesting that early exposure may indeed result in a preference for low-SF information, presumably, because there is a faster, more direct, neural pathway [39,64]. Why happiness would be an exception to this is currently unclear.

Although the hybrid paradigm has been successfully used to study the preference of SF information in the perception of various visual stimuli, including objects [35,37,43], scenes [2,41,42,56], and face-related information (e.g. gender and expression [10,11,31–34,46,47,55,69]), the appearance of hybrid faces is unusual and different from that of a normal face. However, the advantage of this experimental approach is that it allows us to address basic conceptual questions, with careful control of extraneous variability, which would simply not be possible in the 'real word'. A related concern is that the original images were posted by actors instead of genuine expressions. While the usage of well controlled, validated posted prototypical expressions is common and successful in this type of research [3–5,14,27,44,50,58,63], we should be very careful when extending the findings and apply to the perception of facial expressions in the naturalistic environment. It is undoubtedly important to investigate the decoding of pain using genuine, spontaneous facial expressions as stimuli in the relevant studies.

In terms of future directions, it would be interesting to explore more real-world questions, e.g. the usage of SF information when decoding dynamic expressions. In reality, both of our visual percept and the expressions change in time, and whether low-SF or high-SF information would be preferentially used to analyse a pain face at different levels of expressiveness and different stages of perception. Whilst it is difficult to draw direct practical implications from experimental studies of this type, they suggest that low-SF information would be particularly useful when detailed information is difficult to obtain. Examples here would be when expressions are viewed from a distance, in low level visual environments (e.g., at night) or when detailed features are naturally obscured, such as in the case of age-related changes in the face. Indeed, facial wrinkles and folds develop in the course of aging and can make facial expressions of older aged individuals more difficult to decode [15–17,22,25,38]. This seems to be due to the expressiveness of these age-related facial features, which interferes with the emotional facial actions. For example, neutral displays of older age faces have been perceived as showing sadness, happiness or anger, depending on the feature of wrinkles and folds, which in turn could lead to misinterpretations of emotional expressions [16,17,22,38]. These age-related changes are mainly encoded in fine-detailed high-SF information [40,45,57]. Therefore, when perceptual conditions are challenging, it would seem adaptive if observers could decode pain expressions based on preferential processing of low-SF facial information, and less affected by high-SF features as this may introduce an expressive signal and render pain expressions more ambiguous.

In sum, the three experiments confirmed that low-SF information has a perceptual advantage, preferred by observers over high-SF when viewing expressions of pain. An efficient decoding process of pain expressions is suggested, in which the characteristic information (i.e. low-SF) is preferentially perceived and presumably effectively analysed. The preference of SF information is modified by time – low-SF preference was largest when the presentation was brief, and reduced as the presentation duration increased. It seems that when decoding pain expressions, we first notice the overall structural features of pain conveyed by coarse low-SF information, and the fine-detailed high-SF information is integrated at a later stage. Moreover, there are possible sex differences in the way how pain expressions are recognised, e.g. women may be more sensitive to pain-related fine details than men in some situations, in particular when viewing faces in ambiguous conditions.

Conflict of interest statement

The authors have no conflicts of interest to declare in relation to this article.

Acknowledgments

This research was funded by a Graduate School PhD Scholarship provided by the University of Bath to the first author. The authors would also like to thank Frederic Gosselin for allowing us to use the STOIC database [53], as well granting us permission to reproduce the image presented in Figure 1 of this article.

References

[1] Bar M. Visual objects in context. Nat. Rev. Neurosci. 2004;5:617–29. doi:10.1038/nrn1476.

[2] Brady TF, Oliva A. Spatial frequency integration during active perception: perceptual hysteresis when an object recedes. Front. Psychol. 2012;3:462. doi:10.3389/fpsyg.2012.00462.

[3] Calder AJ, Young AW, Keane J, Dean M. Configural information in facial expression perception. J. Exp. Psychol. Hum. Percept. Perform. 2000;26:527–51. doi:10.1037/0096-1523.26.2.527.

[4] Calvo MG, Lundqvist D. Facial expressions of emotion (KDEF): Identification under different display-duration conditions. Behav. Res. Methods 2008;40:109–115. doi:10.3758/BRM.40.1.109.

[5] Calvo MG, Nummenmaa L. Eye-movement assessment of the time course in facial expression recognition: Neurophysiological implications. Cogn. Affect. Behav. Neurosci. 2009;9:398–411. doi:10.3758/cabn.9.4.398.

[6] Calvo MG, Nummenmaa L. Perceptual and affective mechanisms in facial expression recognition: An integrative review. Cogn. Emot. 2015:1–26. doi:10.1080/02699931.2015.1049124.

[7] De Cesarei A, Codispoti M. Spatial frequencies and emotional perception. Rev. Neurosci. 2013;24:89–104. doi:10.1515/revneuro-2012-0053.

[8] Clark-Carter D. Quantitative Psychological Research: The Complete Student’s Companion. Taylor & Francis, 2009.

[9] Czekala C, Mauguière F, Mazza S, Jackson PL, Frot M. My brain reads pain in your face, before knowing your gender. J. pain 2015. doi:10.1016/j.jpain.2015.09.006.

[10] Deruelle C, Fagot J. Categorizing facial identities, emotions, and genders: Attention to high- and low-spatial frequencies by children and adults. J. Exp. Child Psychol. 2005;90:172–184. doi:10.1016/j.jecp.2004.09.001.

[11] Deruelle C, Rondan C, Salle-Collemiche X, Bastard-Rosset D, Da Fonséca D. Attention to low- and high-spatial frequencies in categorizing facial identities, emotions and gender in children with autism. Brain Cogn. 2008;66:115–23. doi:10.1016/j.bandc.2007.06.001.

[12] DeValois RL, DeValois KK. Spatial Vision. Oxford University Press, 1990.

[13] DiCarlo JJ, Maunsell JH. Form representation in monkey inferotemporal cortex is virtually unaltered by free viewing. Nat. Neurosci. 2000;3:814–21. doi:10.1038/77722.

[14] Elfenbein HA, Ambady N. When familiarity breeds accuracy: Cultural exposure and facial emotion recognition. J Pers Soc Psychol 2003;85:276–290. doi:10.1037/0022-3514.85.2.276.

[15] Fölster M, Hess U, Hühnel I, Werheid K. Age-Related Response Bias in the Decoding of Sad Facial Expressions. Behav. Sci. 2015;5:443–60. doi:10.3390/bs5040443.

[16] Fölster M, Hess U, Werheid K. Facial age affects emotional expression decoding. Front. Psychol. 2014;5:30. doi:10.3389/fpsyg.2014.00030.

[17] Freudenberg M, Adams RB, Kleck RE, Hess U. Through a glass darkly: facial wrinkles affect our processing of emotion in the elderly. Front. Psychol. 2015;6:1476. doi:10.3389/fpsyg.2015.01476.

[18] Gold JM, Barker JD, Barr S, Bittner JL, Bromfield WD, Chu N, Goode RA, Lee D, Simmons M, Srinath A. The efficiency of dynamic and static facial expression recognition. J. Vis. 2013;13. doi:10.1167/13.5.23.

[19] Hall JA. Gender effects in decoding nonverbal cues. Psychol. Bull. 1978;85:845–857. doi:10.1037/0033-2909.85.4.845.

[20] Hall JA. Nonverbal sex differences: Accuracy of communication and expressive style. Baltimore, MD, US: Johns Hopkins University Press, 1990.

[21] Harris CM, Hainline L, Abramov I, Lemerise E, Camenzuli C. The distribution of fixation durations in infants and naive adults. Vision Res. 1988;28:419–432. doi:10.1016/0042-6989(88)90184-8.

[22] Hass NC, Schneider EJS, Lim S-L. Emotional expressions of old faces are perceived as more positive and less negative than young faces in young adults. Front. Psychol. 2015;6:1–10. doi:10.3389/fpsyg.2015.01276.

[23] Hegdé J. Time course of visual perception: coarse-to-fine processing and beyond. Prog. Neurobiol. 2008;84:405–39. doi:10.1016/j.pneurobio.2007.09.001.

[24] Henderson JM, Hollingworth A. Eye movements during scene viewing: an overview. In: Underwood G, editor. Eye Guidance in Reading and Scene Perception. New York: Elsevier, 1998. pp. 269–283.

[25] Hess U, Adams RB, Simard A, Stevenson MT, Kleck RE, Kleck RE. Smiling and sad wrinkles: Age-related changes in the face and the perception of emotions and intentions. J. Exp. Soc. Psychol. 2012;48:1377–1380. doi:10.1016/j.jesp.2012.05.018.

[26] Hughes HC, Nozawa G, Kitterle F. Global Precedence, Spatial Frequency Channels, and the Statistics of Natural Images. J. Cogn. Neurosci. 1996;8:197–230. doi:10.1162/jocn.1996.8.3.197.

[27] Kappesser J, Williams AC de C. Pain and negative emotions in the face: judgements by health care professionals. Pain 2002;99:197–206. doi:10.1016/s0304-3959(02)00101-x.

[28] Keogh E. Gender differences in the nonverbal communication of pain: A new direction for sex, gender, and pain research? Pain 2014;155:1927–1931. doi:10.1016/j.pain.2014.06.024.

[29] Keogh E, Holdcroft A. Sex differences in pain: Evolutionary links to facial pain expression. Behav. Brain Sci. 2002;25:465–466. doi:10.1017/S0140525X02320089.

[30] Kret ME, De Gelder B. A review on sex differences in processing emotional signals. Neuropsychologia 2012;50:1211–21. doi:10.1016/j.neuropsychologia.2011.12.022.

[31] Laeng B, Profeti I, Sæther L, Adolfsdottir S, Lundervold AJ, Vangberg T, Øvervoll M, Johnsen SH, Waterloo K. Invisible expressions evoke core impressions. Emotion 2010;10:573–586. doi: 10.1037/a0018689.

[32] Laeng B, Sæther L, Holmlund T, Wang CEA, Waterloo K, Eisemann M, Halvorsen M. Invisible emotional expressions influence social judgments and pupillary responses of both depressed and non-depressed individuals. Front. Psychol. 2013;4:291. doi:10.3389/fpsyg.2013.00291.

[33] Langner O, Becker ES, Rinck M. Higher sensitivity for low spatial frequency expressions in social anxiety: Evident in indirect but not direct tasks? Emotion 2012;12:847–851. doi:10.1037/a0028761.

[34] Laprevote V, Oliva A, Delerue C, Thomas P, Boucart M. Patients with schizophrenia are biased toward low spatial frequency to decode facial expression at a glance. Neuropsychologia 2010;48:4164–4168. doi: 10.1016/j.neuropsychologia.2010.10.017.

[35] Laprevote V, Oliva A, Ternois A-S, Schwan R, Thomas P, Boucart M. Low Spatial Frequency Bias in Schizophrenia is Not Face Specific: When the Integration of Coarse and Fine Information Fails. Front. Psychol. 2013;4:248. doi:10.3389/fpsyg.2013.00248.

[36] Liu J, Harris A, Kanwisher N. Stages of processing in face perception: an MEG study. Nat. Neurosci. 2002;5:910–6. doi:10.1038/nn909.

[37] Majaj NJ, Pelli DG, Kurshan P, Palomares M. The role of spatial frequency channels in letter identification. Vision Res. 2002;42:1165–1184. doi:10.1016/S0042-6989(02)00045-7.

[38] Malatesta CZ, Fiore MJ, Messina JJ. Affect, personality, and facial expressive characteristics of older people. Psychol. Aging 1987;2:64–9. doi:10.1037/0882-7974.2.1.64.

[39] Méndez-Bértolo C, Moratti S, Toledano R, Lopez-Sosa F, Martínez-Alvarez R, Mah YH, Vuilleumier P, Gil-Nagel A, Strange BA. A fast pathway for fear in human amygdala. Nat. Neurosci. 2016;19:1041–1049. doi:10.1038/nn.4324.

[40] Morrison DJ, Schyns PG. Usage of spatial scales for the categorization of faces, objects, and scenes. Psychon. Bull. Rev. 2001;8:454–469. doi:10.3758/BF03196180.

[41] Mu T, Li S. The neural signature of spatial frequency-based information integration in scene perception. Exp. Brain Res. 2013;227:367–377. doi:10.1007/s00221-013-3517-1.

[42] Oliva A, Schyns PG. Coarse blobs or fine edges? Evidence that information diagnosticity changes the perception of complex visual stimuli. Cogn. Psychol. 1997;34:72–107. doi:10.1006/cogp.1997.0667.

[43] Otsuka Y, Ichikawa H, Kanazawa S, Yamaguchi MK, Spehar B. Temporal dynamics of spatial frequency processing in infants. J. Exp. Psychol. Hum. Percept. Perform. 2014;40:995–1008. doi:10.1037/a0035440.

[44] Palermo R, Coltheart M. Photographs of facial expression: Accuracy, response times, and ratings of intensity. Behav. Res. Methods, Instruments, Comput. 2004;36:634–638. doi:10.3758/BF03206544.

[45] Parker DM, Lishman JR, Hughes J. Role of coarse and fine spatial information in face and object processing. J. Exp. Psychol. Hum. Percept. Perform. 1996;22:1448–1466. doi:10.1037/0096-1523.22.6.1448.

[46] Pourtois G, Dan ES, Grandjean D, Sander D, Vuilleumier P. Enhanced extrastriate visual response to bandpass spatial frequency filtered fearful faces: time course and topographic evoked-potentials mapping. Hum. Brain Mapp. 2005;26:65–79. doi:10.1002/hbm.20130.

[47] Prete G, Laeng B, Tommasi L. Lateralized hybrid faces: Evidence of a valence-specific bias in the processing of implicit emotions. Laterality 2014;19:439–54.

doi:10.1080/1357650X.2013.862255.

[48] Prkachin KM. Assessing pain by facial expression: facial expression as nexus. Pain Res. Manag. 2009;14:53–8. doi:10.1155/2009/542964.

[49] Ratcliff R. Methods for dealing with reaction time outliers. Psychol. Bull. 1993;114:510–532. doi:10.1037/0033-2909.114.3.510.

[50] Recio G, Schacht A, Sommer W. Classification of dynamic facial expressions of emotion presented briefly. Cogn. Emot. 2013;27:1486–1494. doi:10.1080/02699931.2013.794128.

[51] Reicherts P, Wieser MJ, Gerdes ABM, Likowski KU, Weyers P, Mühlberger A, Pauli P. Electrocortical evidence for preferential processing of dynamic pain expressions compared to other emotional expressions. Pain 2012;153:1959–1964. doi:10.1016/j.pain.2012.06.017.

[52] Roy C, Blais C, Fiset D, Rainville P, Gosselin F. Efficient information for recognizing pain in facial expressions. Eur. J. Pain 2015;19:852–60. doi:10.1002/ejp.676.

[53] Roy S, Roy C, Fortin I, Ethier-Majcher C, Belin P, Gosselin F. A dynamic facial expression database. J. Vis. 2007;7:944. doi:10.1167/7.9.944.

[54] Ruiz-Soler M, Beltran F. Face perception: An integrative review of the role of spatial frequencies. Psychol. Res. 2006;70:273–292. doi:10.1007/s00426-005-0215-z.

[55] Schyns PG, Oliva A. Dr. Angry and Mr. Smile: when categorization flexibly modifies the perception of faces in rapid visual presentations. Cognition 1999;69:243–65. doi:10.1016/S0010-0277(98)00069-9.

[56] Schyns PG, Oliva A. FROM BLOBS TO BOUNDARY EDGES: Evidence for Time- and Spatial-Scale-Dependent Scene Recognition. Psychol. Sci. 1994;5:195–200. doi:10.1111/j.1467-9280.1994.tb00500.x.

[57] Sergent J. Microgenesis of face perception. In: Ellis HD, Jeeves MA, Newcombe F, Young A, editors. Aspects of Face Processing. Dordrecht: Springer Netherlands, 1986. pp. 17–33. doi:10.1007/978-94-009-4420-6.

[58] Simon D, Craig KD, Gosselin F, Belin P, Rainville P. Recognition and discrimination of prototypical dynamic expressions of pain and emotions. Pain 2008;135:55–64. doi:10.1016/j.pain.2007.05.008.

[59] Sowden PT, Schyns PG. Channel surfing in the visual brain. Trends Cogn. Sci. 2006;10:538–45. doi:10.1016/j.tics.2006.10.007.

[60] Tabachnick BG, Fidell LS. Using Multivariate Statistics. Pearson Education, Limited, 2012.

[61] Thorpe S, Fize D, Marlot C. Speed of processing in the human visual system. Nature 1996;381:520–2. doi:10.1038/381520a0.

[62] Thorpe SJ. NEUROSCIENCE: Seeking Categories in the Brain. Science 2001;291:260–263. doi:10.1126/science.1058249.

[63] Tottenham N, Tanaka JW, Leon AC, McCarry T, Nurse M, Hare TA, Marcus DJ, Westerlund A, Casey BJ, Nelson C. The NimStim set of facial expressions: judgments from untrained research participants. Psychiatry Res. 2009;168:242–9. doi:10.1016/j.psychres.2008.05.006.

[64] Vuilleumier P, Armony JL, Driver J, Dolan RJ, Armony Jorge LL, Driver J, Dolan

Raymond JJ. Distinct spatial frequency sensitivities for processing faces and emotional expressions. Nat. Neurosci. 2003;6:624–31. doi:10.1038/nn1057.

[65] Wang S, Eccleston C, Keogh E. The role of spatial frequency information in the recognition of facial expressions of pain. Pain 2015;156:1670–1682. doi:10.1097/j.pain.0000000000000226.

[66] Wiesenfeld-Hallin Z. Sex differences in pain perception. Gend. Med. 2005;2:137–145. doi:10.1016/S1550-8579(05)80042-7.

[67] Williams AC de C. Facial expression of pain: An evolutionary account. Behav. Brain Sci. 2002;25:439–488. doi:10.1017/S0140525X02000080.

[68] Williams AC de C, Craig KD. Updating the definition of pain. Pain 2016;157:2420–2423. doi:10.1097/j.pain.0000000000000613.

[69] Winston JS, Vuilleumier P, Dolan RJ. Effects of Low-Spatial Frequency Components of Fearful Faces on Fusiform Cortex Activity. Curr. Biol. 2003;13:1824–1829. doi:10.1016/j.cub.2003.09.038.

Figure Captions

Figure 1: Example images used in the experiments. The image on the left represents low-SF pain and high-SF neutral, whereas the image on the right comprises of low-SF neutral & high-SF pain information. The original images are obtained from the STOIC database [53], and the hybrid images are reproduced with permission from Frederic Gosselin.

Figure 2: Female and male participants' preference towards low-SF expressions when pain and neutral were presented in the low-SF component in hybrid faces in Experiment 1 (error bars reflect SEM).

Figure 3: Mean preference towards low-SF expressions when pain and happiness were presented in the low-SF component in hybrid faces with each presenting duration in Experiment 3 (error bars represent SEM).

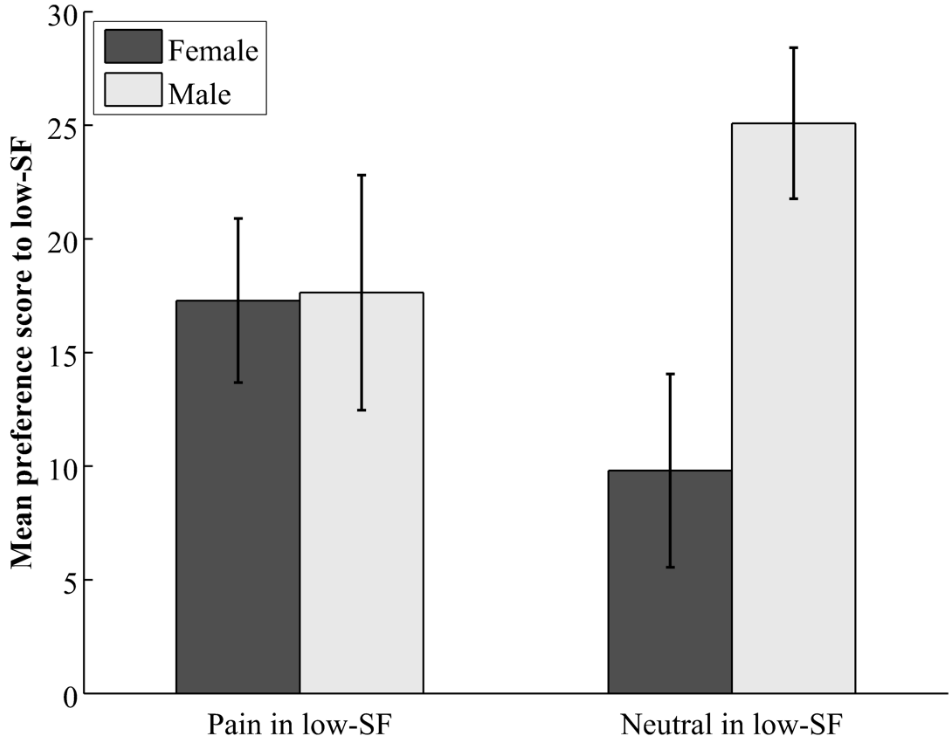
30
25
20
15
10
5
0
Female
Male
Mean preference score to low-SF
Pain in low-SF
Neutral in low-SF

Figure 2

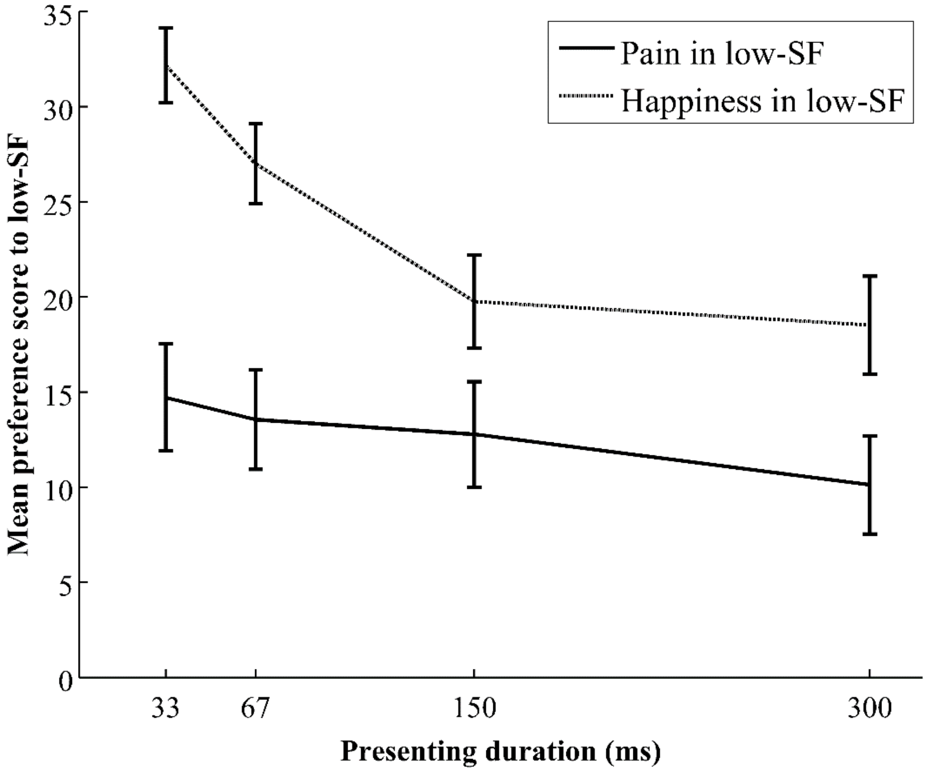
Pain in low-SF
Happiness in low-SF
Mean preference score to low-SF
35
30
25
20
15
10
5
0
33
67
150
300
Presenting duration (ms)

Figure 3

Table 1 Percentage of responses based on low-SF and high-SF information, and the result of the binomial test (two-tailed; test proportion = 50%) for each hybrid face combination in each condition by female and male participants in Experiment 1 (pain-neutral hybrids).

		Low-SF pain & high-SF neutral				Low-SF neutral & high-SF pain			
		Low-SF	High-SF	Exact *p*	Cohen's *g*	Low-SF	High-SF	Exact *p*	Cohen's *g*
Female	33 ms	73%	27%	< .001	0.23	68%	32%	< .001	0.18
(n = 23)	67 ms	70%	30%	< .001	0.20	59%	41%	< .001	0.09
	150 ms	66%	34%	< .001	0.16	54%	46%	.012	0.04
	300 ms	62%	38%	< .001	0.12	59%	41%	< .001	0.09
Male	33 ms	71%	29%	< .001	0.21	81%	19%	< .001	0.31
(n = 20)	67 ms	69%	31%	< .001	0.19	76%	24%	< .001	0.26
	150 ms	67%	33%	< .001	0.17	73%	27%	< .001	0.23
	300 ms	67%	33%	< .001	0.17	75%	25%	< .001	0.25

Table 2 Mean (SD) of the preference score towards low-SF information in hybrid faces for female and male participants in Experiment 1 (pain-neutral hybrids).

		33 ms	67 ms	150 ms	300 ms
Female	Low-SF pain & high-SF neutral	23.13 (19.25)	19.39 (20.55)	15.26 (18.95)	11.35 (17.87)
(n = 23)	Low-SF neutral & high-SF pain	17.35 (22.50)	8.91 (24.30)	3.70 (21.21)	8.83 (20.07)
Male	Low-SF pain & high-SF neutral	20.25 (26.13)	17.95 (23.75)	16.45 (24.78)	15.90 (24.90)
(n = 20)	Low-SF neutral & high-SF pain	29.25 (13.33)	24.65 (19.51)	22.30 (16.61)	24.15 (16.28)

Table 3 Percentage of responses based on low-SF and high-SF information, and the result of the binomial test (two-tailed; test proportion = 50%) for each hybrid face combination in each condition by female and male participants in Experiment 2 (pain-fear hybrids).

		Low-SF pain & high-SF fear				Low-SF fear & high-SF pain			
		Low-SF	High-SF	Exact *p*	Cohen's *g*	Low-SF	High-SF	Exact *p*	Cohen's *g*
Female	33 ms	66%	34%	< .001	0.16	63%	37%	< .001	0.13
(*n* = 23)	67 ms	60%	40%	< .001	0.10	60%	40%	< .001	0.10
	150 ms	56%	44%	< .001	0.06	57%	43%	< .001	0.07
	300 ms	59%	41%	< .001	0.09	53%	47%	.050	0.03
Male	33 ms	67%	33%	< .001	0.17	67%	33%	< .001	0.17
(*n* = 20)	67 ms	62%	38%	< .001	0.12	62%	38%	< .001	0.12
	150 ms	62%	38%	< .001	0.12	60%	40%	< .001	0.10
	300 ms	58%	42%	< .001	0.08	59%	41%	< .001	0.09

Table 4 Mean (SD) of the preference score towards low-SF information in hybrid faces for female and male participants in Experiment 2 (pain-fear hybrids).

		33 ms	67 ms	150 ms	300 ms
Female	Low-SF pain & high-SF fear	15.00 (13.75)	9.26 (14.34)	5.74 (13.99)	8.35 (13.91)
(n = 23)	Low-SF fear & high-SF pain	12.61 (14.56)	9.91 (15.88)	6.22 (15.34)	2.87 (18.48)
Male	Low-SF pain & high-SF fear	16.20 (18.67)	12.00 (19.77)	11.65 (18.26)	7.20 (19.03)
(n = 20)	Low-SF fear & high-SF pain	16.80 (22.37)	11.80 (20.20)	9.85 (19.90)	8.55 (25.18)

Table 5 Percentage of responses based on low-SF and high-SF information, and the result of the binomial test (two-tailed; test proportion = 50%) for each hybrid face combination in each condition by female and male participants in Experiment 3 (pain-happiness hybrids).

		Low-SF pain & high-SF happiness				Low-SF happiness & high-SF pain			
		Low-SF	High-SF	Exact *p*	Cohen's *g*	Low-SF	High-SF	Exact *p*	Cohen's *g*
Female	33 ms	66%	34%	< .001	0.16	82%	18%	< .001	0.32
(*n* = 22)	67 ms	61%	39%	< .001	0.11	78%	22%	< .001	0.28
	150 ms	60%	40%	< .001	0.10	70%	30%	< .001	0.20
	300 ms	57%	43%	< .001	0.07	68%	32%	< .001	0.18
Male	33 ms	65%	35%	< .001	0.15	86%	14%	< .001	0.36
(*n* = 20)	67 ms	68%	32%	< .001	0.18	79%	21%	< .001	0.29
	150 ms	67%	33%	< .001	0.17	72%	28%	< .001	0.22
	300 ms	65%	35%	< .001	0.15	72%	28%	< .001	0.22

Table 6 Mean (SD) of the preference score towards low-SF information in hybrid faces for female and male participants in Experiment 3 (pain-happiness hybrids).

		33 ms	67 ms	150 ms	300 ms
Female	Low-SF pain & high-SF happiness	15.32 (17.63)	10.32 (17.28)	10.09 (18.82)	6.77 (19.19)
(n = 22)	Low-SF happiness & high-SF pain	31.82 (13.33)	27.18 (12.82)	19.50 (12.02)	17.27 (16.80)
Male	Low-SF pain & high-SF happiness	14.05 (19.21)	17.10 (16.39)	15.75 (16.86)	13.80 (13.10)
(n = 20)	Low-SF happiness & high-SF pain	33.40 (10.62)	26.80 (14.63)	20.05 (19.59)	19.90 (16.89)