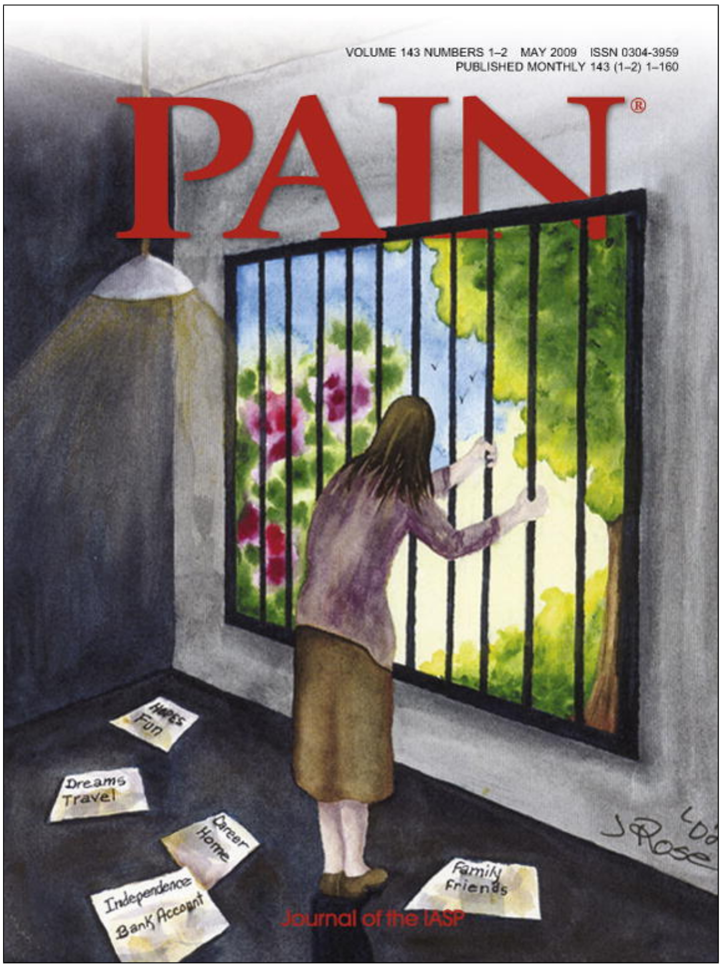
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Unconscious affective processing and empathy: An investigation of subliminal priming on the detection of painful facial expressions

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ABSTRACT

Results from recent functional neuroimaging studies suggest that facial expressions of pain trigger empathic mimicry responses in the observer, in the sense of an activation in the pain matrix. However, pain itself also signals a potential threat in the environment and urges individuals to escape or avoid its source. This evolutionarily primitive aspect of pain processing, i.e., avoidance from the threat value of pain, seems to conflict with the emergence of empathic concern, i.e., a motivation to approach toward the other. The present study explored whether the affective values of targets influence the detection of pain at the unconscious level. We found that the detection of pain was facilitated by unconscious negative affective processing rather than by positive affective processing. This suggests that detection of pain is primarily influenced by its inherent threat value, and that empathy and empathic concern may not rely on a simple reflexive resonance as generally thought. The results of this study provide a deeper understanding of how fundamental the unconscious detection of pain is to the processes involved in the experience of empathy and sympathy.

1. Introduction

By virtue of its aversiveness, pain serves to promote an organism's health and integrity, to the extent that congenital absence of pain on injury significantly shortens human life [8]. Facial expressions of pain have important survival value. The individual expressing pain may derive benefit if expressions of pain are reliably followed by actions by observers which promote recovery and survival; protect from danger; and aid in obtaining basic requirements [25]. Therefore, facial signals of pain demand rapid detection, success of which will be transformed into adaptive affective and behavioral responses from the observer, including sympathy for the target [17].

A growing number of neuroimaging studies demonstrate a striking overlap in the neural underpinnings of the first-hand experience of pain and its perception in others [6,20]. These findings lend credence to the idea that empathy for pain draws partly upon automatic sensorimotor resonance between others and self, offering a possible, yet only partial route to understanding the mental states of others [10]. It is worth mentioning that activation of these regions (insula, periaqueductal gray and anterior cingulate cortex) may reflect a general aversive response. Although this somatic sensorimotor resonance is elicited by the mere perception of pain in others, it is also modulated by various social, motivational, and cognitive factors [3,18,23]. For example, pain of likable others who played a game fairly resulted in an enhancement of empathic brain responses, whereas that of dislikable ones who played unfairly did not [27]. The level of resonance, therefore, seems to be influenced by motivational factors as well as by actor-observers interpersonal relationships.

However, pain itself not only is an unpleasant emotional experience for the self, but also signals a potential threat in the environment and urges observers to escape its source. This evolutionarily primitive process of pain, i.e., avoidance from the threat value of pain, in theory, seems to conflict with the emergence of empathic concern, i.e., approach toward the other. In other words, it is unclear how detected pain loses its demanding threat values and guides approaching empathic behavior. The present study investigated this unexplored issue by adopting an affective priming procedure in which pain facial expressions were coupled with likable and dislikable traits. If the detection of pain competes with its inherently threatening demands, it follows that manipulating the affective significance of targets in pain should bias its detection, i.e., enhanced detection of pain for faces associated with positive values, but lessened detection of pain for those associated with negative values. If the detection of pain is hardwired to signal harm and threat, and has a minimal role in the empathic concern, the primitive defensive system will function to limit the impact of affective characteristics on the detection of pain, i.e., an enhanced

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vigilance to pain detection facilitated by negatively labeled faces in accordance with the affective priming literature (e.g., [24]). Furthermore, it is known that the level of empathic disposition varies between individuals [1,4–6]. The present study also explored whether dispositional level in empathy is related to the detection of pain.

2. Methods

2.1. Participants

Participants included 33 right-handed healthy female subjects (mean age = 21.5 ± 2) recruited from the University of Chicago community through an electronic newsgroup posting. None had a neurological or psychiatric history. All participants provided informed written consent, and were paid for their participation. The study was approved by the IRB Committee from the University of Chicago.

2.2. Design

Likable and dislikable affective values were subliminally tagged to faces using a priming technique. Faces expressed mixed expressions of pain and happiness, and the subjects' task was to judge whether the face was expressing pain or not. Participants underwent two blocks; in the first block, faces were not associated with primed values, and in the second block, they were. Pain detection was analyzed with the Signal Detection Theory (SDT) as modeled in Fig. 1.

2.3. Stimuli

Four words with a higher likableness rating on a six-point scale (honest, kind, caring, loyal; mean = 5.6) and words with a lower likable rating (rude, liar, cruel, selfish; mean = 1.4) were selected from the Dumas 844 word list [13], both of which were matched with familiarity ratings (all above 5.8). Scrambled words were used for the non-affective priming as a neutral condition. Pained and happy faces from three males were taken from a set of stimuli developed and validated by Simon and colleagues [26]. The faces were morphed with Abrosoft FantaMorph 3 software to create single faces expressing varying intensities of pain and happiness. Faces in the middle (i.e., 50% of pain and happiness) were used as target faces. A distinct study with 19 participants (10 females, mean age = 27.6 ± 4.7) was conducted to validate those stimuli and make sure that they convey a similar degree of perceived pain and happy intensities (ranges of mean *z*-scores are between −0.2 and 0.1, and between −0.4 and 0.1, respectively)[1]. Faces with a lower degree of pain (25%, 30%, 35%, 40%) (mean *z*-scores are less than −0.3 for pain intensity and are above 0.3 for happiness intensity) and those with a higher degree of pain (60%, 65%, 70%, 75%) (mean *z*-scores are above 0.6 for pain intensity and are less than −0.6 for happiness intensity) were used as foil stimuli. Presentation of stimuli and measurement of responses were controlled by the software package DirectRT (http://www.empirisoft.com/directrt/).

2.4. Procedure

The procedure began with 15 practice trials, followed by two test blocks: block 1 (unprimed) and block 2 (primed). The participants were required to make a judgment as quickly and as accurately as possible as to whether the face expressed pain or not by clicking either the left or right mouse button with their right index and middle fingers. Assignments of right and left keys for pain and no-pain were randomized between participants. The sequence of events on each trial is illustrated in Fig. 2.

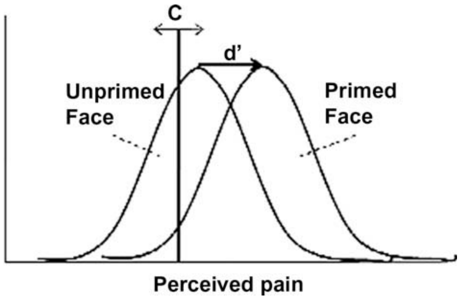

Fig. 1. Hypothetical normal distributions representing unprimed and primed faces for signal detection analyses.

A preliminary study with 40 participants (who did not take part in the actual experiment) was conducted to select the psychophysics parameters. The refresh rate of the screen was set at 120 Hz. In order to ensure that the prime words were not recognizable (i.e., unconscious), prime duration was decreased from 42 ms (5 frames) until none of the subjects could recognize the presence of prime. Thus, 25 ms (3 frames) of prime duration was chosen. There were 576 trials in total, with 288 trials (216 targets and 72 foils) in each block. Each block was composed of six sessions. Each session contained 48 trials (36 targets and 12 foils). The same face was always tagged with the same affective values in block 2 (e.g., Male1 with likable, Male2 with dislikable, Male3 with scrambled), and the combination of male figures and affective values was randomized between subjects. The presence of the prime was not mentioned to the participants. To check that they were not aware of prime stimuli, we used an extensive debriefing procedure in which participants were asked increasingly specific questions about the study. This procedure revealed that none of the participants were aware of the priming manipulation. After completing the experiment, participants were asked to fill out two self reports dispositional measures: the Empathy Quotient [EQ] [1] and the Interpersonal Reactivity Index [IRI] [7].

2.5. Signal detection analysis

Data obtained from target faces were analyzed. SDT yields estimates of sensitivity to the presence of pain, a statistic called d', and the criterion for the decision to judge pain, a statistic called C. The sensitivity to the presence of pain at zero indicates chance level (null d') in detecting the presence of pain in primed faces versus in unprimed faces. Positive deviations from zero in d' indicate an above-chance level of sensitivity to the presence of pain, and negative deviations indicate an above-chance level of decreased sensitivity to the presence of pain in primed faces. If the criterion to judge pain (C) is at zero, it indicates no greater tendency to make a pain judgment than a no-pain judgment. Deviation from zero in a positive direction indicates a bias favoring no-pain judgment, and deviations in a negative direction indicate a bias to judge pain. These two values were calculated under the following assumption: a "hit" corresponded to a "pain" response in block 2; a "miss" corresponded to a "no-pain" response in block 2; a "false alarm" corresponded to a "pain" response in block 1; a "correct rejection" corresponded to a "no-pain" response in block 1. Since SDT values were analyzed over the same face between 2 blocks, unchanged physical features of faces are not supposed to yield these values (d' and C) deviant from zero. Therefore, experimental conditions

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[1] The intensity ratings were obtained by a 10-point scale of 0 (not at all) to 9 (very much). In order to minimize the individual differences in ratings, each rating score was transformed into *z* scores.

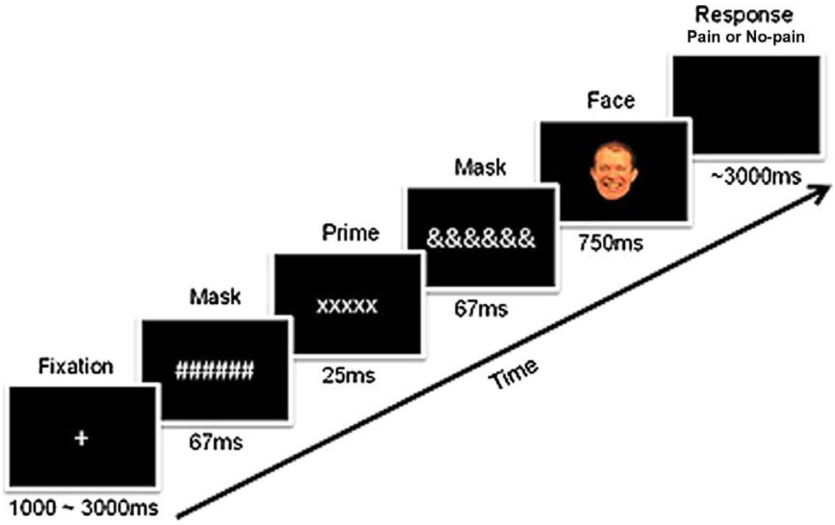

Fig. 2. Experimental paradigm. Each priming word was preceded by a 67-ms mask made of ten hash-mask symbols, and was followed by a 67-ms ampersands backward mask.

were compared by using one-sample t tests, with a criterion of $p < 0.05$ using SPSS 12.0.

2.6. Correlation analyses

Indices of affective bias were computed on the basis of sensitivity ([d' likable – d' neutral] and [d' dislikable – d' neutral]) and criteria ([C likable – C neutral] and [C dislikable – C neutral]). We then conducted exploratory analyses of the relationships between each of these indices and the questionnaire measures obtained.

3. Results

There was no significant difference between the three affective conditions in response time in block 2 ($F(2,96) = 0.143$, $p = 0.87$) nor in the response time difference between block 2 and block 1 ($F(2,96) = 0.061$, $p = 0.94$) (Table 1). The signal detection analysis revealed that the pain sensitivity to primed faces versus unprimed faces was significantly above-chance level in all three conditions [neutral (mean $d' = 0.38$, SD = 0.61) ($t(32) = 3.67$, $p < 0.01$, Cohen's $D = 1.3$), likable (mean $d' = 0.43$, SD = 0.72) ($t(32) = 3.47$, $p < 0.01$, Cohen's $D = 1.2$), and dislikable (mean $d' = 0.28$, SD = 0.66) ($t(32) = 2.45$, $p < 0.05$, Cohen's $D = 0.87$)]. The criterion to judge the face as in pain was significantly different from zero in the dislikable condition (mean $C = -0.46$, SD = 0.7) ($t(32) = -3.70$, $p < 0.01$, Cohen's $D = -1.3$), but not in the neutral (mean $C = -0.24$, SD = 1.2) ($t(32) = -1.20$, $p = 0.24$, Cohen's $D = -0.42$) or likable (mean $C = -0.13$, SD = 1.1) ($t(32) = -0.67$, $p = 0.51$, Cohen's $D = -0.24$) condition. Correlation analyses revealed that dislikable d' bias was positively correlated with the fantasy scale of IRI ($r = 0.59$, $p < 0.01$) (Table 2). The fantasy scale of the IRI measures the tendency to transpose oneself into fictional situations.

Table 1
Response times.

	Block 1		Block 2	
	M	SD	*M*	SD
Neutral priming	1125	415	979	376
Likable priming	1128	396	977	368
Dislikable priming	1154	414	1021	376

4. Discussion

The present study investigated how the detection of painful facial expressions is affected by the affective characteristics of others who are in pain. Attention theory posits that the threat value of pain is evolutionarily and ontogenetically primitive, and requires attentional resources [14]. This theory provides a facilitated

Table 2
Correlations of affective bias with questionnaire measures.

		Sensitivity d'		Criterion C		EQ	IRI		
		Likable bias	Dislikable bias	Likable bias	Dislikable bias		FS	PT	EC
Sensitivity d'	Likable bias								
	Dislikable bias	0.29							
Criterion C	Likable bias	0.04	−0.21						
	Dislikable bias	0.14	0.00	0.51**					
EQ		0.13	−0.11	−0.07	0.07				
IRI	FS	0.04	0.58**	−0.21	0.04	0.13			
	PT	−0.22	−0.28	0.15	0.14	0.70**	0.10		
	EC	0.06	-0.03	0.15	0.07	0.50**	0.28	0.48**	
	PD	0.08	0.00	0.33	0.24	−0.24	0.27	0.05	0.30

EQ, empathy quotient; IRI, interpersonal reactivity index; FS, fantasy scale; PT, perspective-taking; EC, empathic concern; PD, personal distress.
** $p \leqslant 0.01$.

detection of pain in negatively associated faces. On the other hand, the current models of empathy attach importance to the positive relationship between a target in pain and an observer [12], and would predict facilitated pain detection in faces primed with likable traits and impeded detection in faces primed with dislikable features.

Our results showed that the *d*′ value was increased in all affective conditions, but the *C* value was decreased only in faces with dislikable priming. That is participants became sensitive to the presence of pain regardless of affective values, but used a more lenient threshold (a greater tendency to judge pain) when the face was tagged by a dislikable value. Thus, the results of the present study provide some support for a primitive role of automatic pain detection that is related primarily to threat processing and minimally to empathic processing.

Functional imaging studies that investigated the neural correlates of empathy for pain have provided evidence of the activation of a shared neural circuit in the pain matrix between perceivers and observers [6,20], which has been interpreted as the automatic and bottom-up processing component of empathy. Although perceived pain has at least two dissociable characteristics, such as its inherent threat value and its prosocial-motivational value, the relationship between the two is still poorly understood. One electrophysiological study recently provided evidence for differential processes of empathy for pain between the early and the late stages [15], where an early component of the empathic response was not influenced by the shift of attention, but the late component depended on the focus of attention. If this applies to our SDT data, the enhanced sensitivity for pain, which was not influenced by the affective characteristics of faces, may correspond to the very early stage of pain detection processing, and biased judgments of pain in negatively associated faces could be related to the late stage of processing. However, our results showed that the detection of pain was influenced not by the positive but by the negative affective value of targets in pain. This finding suggests that both the early and late stages of information processing reflect detection of the threat value of pain rather than the automatic emotional sharing that is hypothesized to occur at a very early stage [28]. Our findings further indicate that the automatic emotional sharing may not be the earliest or foremost process as generally believed. Threat-related processing may be occurring already, or at the same time, and threat resolution should also be taking place.

It should be noted, however, that the results obtained in the present study could be associated with the possible gender difference in empathy. Compared to male participants, females often perform better in emotional tasks (e.g., [22]), and show more empathic brain responses to others' emotions [4] and pain [5,19], even toward dislikable targets [27]. Thus, general sensitivity to the pain across affective values could also be associated with better emotion detection or stronger empathic response that females may possess.

Another possible mechanism accounting for the enhanced sensitivity of pain is that the faces were presented repeatedly so that familiarization to the faces could have aroused by the end of the first block. Compared to unfamiliar faces, familiar faces evoke stronger brain responses in the face-responsive regions of the ventral extrastriate cortex, as well as in the anterior paracingulate cortex, the superior temporal sulcus/temporoparietal junction, and the precuneus, which are part of the theory of mind network [16]. This raises the possibility that familiarized faces could boost sensitivity to painful facial expressions by recruiting extrastriate structures connected to the circuits underlying pain empathy.

Additionally, we found a positive correlation between dislikable *d*′ bias and the IRI fantasy scale. According to Davis's original study [7], the fantasy scale was associated with shyness, loneliness, and social anxiety. This indicates that individuals with higher dispositional level in shyness, loneliness, and social anxiety are more sensitive to the presence of pain in dislikable faces, which may be due to a greater negative bias related to anxiety [2,21].

Importantly, although the neutral condition (scrambled words) was used as a control in this study, the possible effect of retesting still remains to be solved. If a more adequate control condition, such as a between subject control in which the manipulation in block 2 is lacking, was added, the present study might have yielded stronger results by testing differences between the conditions. Another important limitation of this study is regarding the highly controversial issue of "an unconscious effect". Although "unawareness" was examined in preliminarily subjects, differences in individual threshold in "awareness" were not controlled. Thus, the issue of unawareness should be treated carefully.

Unconscious processing of affective value facilitated attention to the threat value of pain rather than to the automatic empathic resonance. The present study suggests that the mere perception of pain does not automatically activate an empathic sharing response, which is often (and wrongly) assumed to lead to empathic concern or sympathy. On the contrary, what appears to be activated is the threat-detection system. Further research is needed to better understand the functional relationship between the threat-detection system and the affective-motivational empathic system, and in particular how the dissonance between these two systems is resolved. It is possible that what researchers called 'pain empathy' [20], based on the activation of the pain matrix (especially the anterior cingulate cortex, insula and periaqueductal gray), in fact reflects a general aversive response in the observer, and not much empathic concern, which is more sophisticated than the somatic sensorimotor resonance to nociceptive stimuli. Clearly, complex interactions between dispositional and situational factors contribute to social interaction and interpersonal sensitivity [9].

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