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Is Conscious Awareness Required for Facial Pain Detection?

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A growing literature suggests that facial expression of certain emotions, such as fear or anger, may be pre-consciously detectable by observers, possibly facilitating more rapid neural processing for adaptive reasons. Might facial expressions of pain be similarly privileged for pre-conscious detection and processing? In this paper, we provide theoretical reasons for and against this proposition and critically analyze the small amount of empirical data on the question that has been published to date. Although we argue that these data point to a tentative "yes," we also highlight experimental design features that we think could be strengthened going forward.

Keywords: pain, face perception, consciousness, evolutionary psychology

It is now a basic tenet of vision science that conscious attention is a limited resource, and that our typical surroundings are so replete with information (concerning objects, surfaces, agents, and so on) that we cannot actively attend to it all (Moran and Desimone, 2001). One way that evolution has equipped us to face this limitation is to allow for a certain amount of pre-attentive processing of the visual scene (Goodale and Milner, 2013), wherein specialized, low-level neuroreceptors in the retina selectively respond to basic features including color, orientation, and movement (Costandi, 2014), and then broadcast these features to different brain areas to be bound together as representations of coherent objects (Treisman and Gelade, 2001).

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Not all objects are processed in the same way or with the same priority, however. Instead, a great deal of work suggests that fitness-relevant objects in particular (that is, objects whose relatively immediate detection and recognition would have had outsized implications for the survival and reproduction of our ancestors), are subject to privileged processing by the visual system (Öhman, Flykt, and Esteves, 2001). As argued by Brosch, Pourtois, and Sander (2010):

> Sometimes we are confronted with classes of stimuli that have more direct relevance for our well-being and survival than others. For instance, some stimuli may signal danger or threat, such as predators or enemies, whereas other stimuli signal chances for growing and expansion, such as potential mates or food sources. Such stimuli require rapid adaptive responses, such as evading the threat or approaching the positive stimulus. … Given the high importance of such "emotional" stimuli for the organism, the perceptual processing of these stimuli should be prioritized to allow for a rapid appraisal of the situation and consequently the rapid preparation of an appropriate behavioral response. (p. 378)

In line with this prediction, a large body of evidence suggests that certain classes of objects can indeed be (pre)processed by the visual system to a large extent without observer awareness of the input, and then go on to influence subsequent behavior (Amihai, Deouell, and Bentin, 2011).

One of the most well-studied classes of such an object is *faces* (Earp and Everett, 2013; Kanwisher and Yovel, 2006). We begin, therefore, with a brief account of the evidence for faces being specially processed, before zooming in on the question of which category-level *dimensions* of faces can be detected without conscious awareness. In particular, we discuss the evidence for facial *emotions* being pre-attentively processed by the visual system, with a focus on fear and anger. Early detection of these emotions has been proposed to have been adaptively important for our ancestors. Drawing on similar reasoning, we then propose that facial expressions of pain may be detectable non-consciously, and critically evaluate one of the small number of studies to date — just two — that have investigated this phenomenon empirically.

Faces as Privileged Stimuli

After decades of research and debate, it is now widely agreed that faces, compared to many other types of stimuli, are processed by the brain in a privileged way (Kanwisher and Yovel, 2006). One aspect of this privilege is the automaticity of facial perception: the ability of the visual system to register faces without the need for subjective awareness.[1]

[1] There is an ongoing debate in the literature about whether faces are processed *qua* faces (or as such), rather than as part of a class of objects for which humans have special expertise in recognition due to abundant experience (Burns et al., 2019; Gauthier et al., 2000; Kanwisher, 2017; Young and Burton, 2018). One of us has written about this debate elsewhere (Earp and Everett, 2013). However, it is tangential to our present purposes, so we will not discuss it further.

According to Palermo and Rhodes (2007), "the emotional significance and neural specificity of face processing make faces an ideal candidate for automatic or pre-attentive processing" (p. 76). Such processing is typically understood to be characterized by the following factors: rapidity (e.g., Batty and Taylor, 2003), lack of conscious awareness (e.g., Bargh, 1997), mandatoriness (e.g., Wojciulik, Kanwisher, and Driver, 1998) and minimal use of attentional resources (e.g., Schneider and Chein, 2003).

Evidence that faces are indeed processed in this manner (i.e., automatically and pre-attentively) comes from several sources. Examples include: studies showing that parts of the fusiform gyrus are selectively activated by heavily masked faces (e.g., Morris, Pelphrey, and McCarthy, 2007; Moutoussis and Zeki, 2002); studies of unilateral neglect patients showing specific brain activity in response to faces presented in the extinguished field, despite patient denial of conscious awareness of the faces (e.g., Driver and Vuilleumier, 2001; Driver, Vuilleumier, Eimer, and Rees, 2001); and studies showing that faces of which participants are not consciously aware can nevertheless modulate electrophysiological activity triggered by the subsequent presentation of faces (e.g., Hoshiyama, Kakigi, Takeshima, Miki, and Watanabe, 2006). All together, it appears that the vision system is capable of categorizing faces prior to, and hence without the need of, conscious awareness, and that these pre-attentively processed faces can directly influence subsequent task behavior.

Subordinate Information: Emotion

While the evidence for low-level categorization of faces is strong and robust, there is less consensus about the type of information that can be extracted non-consciously from faces once they are detected, such as individual personal identity or race or gender (for discussions, see, e.g., Amihai et al., 2011; Moradi, Koch, and Shimojo, 2005; Stone and Valentine, 2005). Nevertheless, there is evidence that at least some categorical facial aspects may be non-consciously detectable. In particular, a number of studies suggest that facial emotion can be registered and processed without conscious awareness of the associated face, as well as affect behavioral responses. As Tamietto and Gelder (2010) note, "the evolution of brain structures that are implicated in emotion processing preceded the emergence of neural systems that are involved in sustaining perceptual consciousness" (p. 697). This may suggest that emotion-detection is an ancient and very basic capacity that would have been possible without subjective awareness.

Among the so-called "basic six" emotions (anger, fear, happiness, sadness, surprise, and disgust),[2] the behavioral evidence for pre-attentive processing of

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[2] For a critique of the view that there are six basic emotions with associated facial expressions that are universally recognized across cultures, see Gendron et al. (2014).

associated facial expressions appears to be strongest for fear and anger (Honk et al., 2001; Öhman et al., 2001; Yang et al., 2007), especially when those emotions are task-relevant (Engen et al., 2017). A common explanation for the special salience of these two emotions is that they are "threat-related," such that their perceptual prioritization would likely have conferred strong adaptive advantages over evolutionary time (Öhman et al., 2001).

Consistent with this idea, findings of pre-attentive fear- and anger-detection derived from behavioral approaches have been reinforced by neuroimaging techniques, which likewise suggest that at least some emotional information can be extracted from faces in the absence of conscious awareness, as inferred from relevant changes in neural activity (Balconi, 2006; Balconi and Lucchiari, 2005; Vuilleumier et al., 2002; Williams et al., 2004). For example, both the amygdala and the superior temporal sulcus can be activated by the presentation of fearful faces below the level of conscious awareness (Pessoa, 2005; Tsuchiya et al., 2009). Subliminally presented angry faces (not consciously perceivable) activate similar neural circuitry as supraliminally presented angry faces (consciously perceivable), while also automatically priming selection of anger-denoting adjectives in a linked behavioral task (Prochnow et al., 2013).

The evidence regarding other facial emotions is somewhat more mixed. Killgore and Yurgelun–Todd (2004) used functional magnetic resonance imaging (fMRI) to study activation in the amygdala and anterior cingulate gyrus as a result of happy and sad faces presented below the normal threshold of conscious perception (i.e., presented for 20 ms and then immediately masked by a neutral face presented for 100 ms). They found that the masked happy faces were associated with significant bilateral activation within the anterior cingulate gyrus and amygdala, while masked sad faces yielded only limited activation within the left anterior cingulate gyrus, and no activation in any other hypothesized brain region (2004, p. 1215). However, the authors failed to statistically correct for multiple comparisons, raising the possibility that at least some of the apparent activation patterns they observed may have been a result of Type 1 error (as they acknowledge on page 1221) [for a theoretical discussion, see Trafimow and Earp (2017)].

More recently, Duan, Dai, Gong, and Chen (2010) presented surprised, happy, or neutral faces for 33 ms followed by a neutral face mask presented for 467 ms, and found that the surprised faces yielded greater activation in the parahippocampal gyrus and fusiform gyrus (previously associated with novelty detection). However, to date there have been no replications of this effect using the same (or a sufficiently similar) paradigm (Earp, 2020), leaving the evidence base for pre-attentive detection of surprise somewhat thin.

Finally, with respect to disgust, Flexas et al. (2013) used facial disgust primes — with happy and neutral faces as controls — presented under brief and extended stimulus onset asynchrony (SOA) conditions (i.e., 20 ms vs. 300 ms) in the context of an affective misattribution paradigm (AMP). The target affective judgment of abstract artwork was influenced by the extended SOA presentation of disgusted faces, but not the brief SOA presentation, suggesting that pre-attentive processing of facial expressions of disgust may not be well-supported. Indeed, using a backward masking paradigm, Lawrence et al. (2007) showed that participants with obsessive–compulsive disorder (OCD), compared to control participants, showed greater activation in response to facial expressions of disgust in the left ventrolateral prefrontal cortex as well as reduced activation in the thalamus. However, this was due to facial stimuli presented just *above* the normal threshold of conscious awareness.

Given such inconsistencies in the available evidence, we might ask why it is that some, but not other, types of information — in this case only certain emotions — appear capable of being "read" off facial stimuli non-consciously. One possibility is that different methodological approaches, including variation in experimental rigor between studies — or even differences in participant characteristics (e.g., sensitivity to briefly-presented stimuli; see Pessoa, 2005) — has led to uneven *evidence* regarding the capacity for non-conscious emotion recognition without this reflecting a true underlying difference in the capacity for such recognition across emotions. For example, Tamietto and Gelder (2010) have noted that earlier studies, in which anger and fear tended to be the focus, may have "overestimated the extent of non-conscious perception of emotional stimuli and identified neural correlates that in fact reflect partial stimulus awareness" (p. 698). However, they also note that "more recent studies with very restrictive (that is, objective) criteria for defining visual awareness" have largely supported the earlier findings (ibid.).

Another possibility, then, is that one should actually expect a difference in non-conscious detectability between anger and fear, on the one hand, and the other emotions, on the other hand, on theoretical grounds. As Amihai et al. (2011, p. 270) note:

> The possibility that different types of physiognomic information pertinent to different levels of subordinate categorization differentially depend on conscious awareness is conceivable since the different kinds of information that are attained from faces are distinctly analyzed, and are not part of a single unitary process.

Thus, it is plausible that some aspects of face processing — including recognition of some types of emotional expression — can occur without awareness, while other aspects cannot.

Special Emotions

What is it about anger and fear, then, that might set them apart from other emotions? It is plausibly not mere negative valence, because sadness, too, is a negatively-valenced emotion. Yet, the evidence for non-conscious detection of facial sadness is relatively thin (see Killgore and Yurgelun–Todd, 2004; but see also Peng et al., 2017). Another possibility, then, concerns the "threat-relatedness" of these emotions, as noted above. Öhman et al. (2001) present the case for this view compellingly:

> … [Since] stimuli related to recurrent survival threats in the environment of evolutionary adaptedness [EEA] may have been selected by evolution to become more or less automatic triggers of attention … one would expect that *threat* stimuli owing their fear-relevance to evolutionary contingencies, such as snakes, spiders, and angry faces would be likely to capture attention quite automatically. (pp. 466–467, emphasis added, internal references omitted)

Following this suggestion, there is empirical evidence in the domain of fear conditioning of instances of highly "prepared" learning, involving threat-related stimuli that are especially relevant for survival, as in the case of specific phobias. This phenomenon has also been termed *evolutionary preparedness* (Öhman and Mineka, 2001). Building on this suggestion, we ask whether facial expressions of *pain* might be pre-attentively processed by the visual system, joining fear and anger as apparently privileged dimensions of facial information processing.

Pain has arguably evolved as a signal of bodily threat, promoting avoidance behavior in order to protect the individual from actual or potential tissue damage. However, pain is also highly social (Karos et al., 2018; Williams, 2002) and is continually communicated via pain behavior, predominantly facial expressions. Thus, facial expressions of pain are akin to those of fear and anger in that they may provide a salient, evolutionarily-primed signal of threat (Yamada and Decety, 2009). Only two empirical studies to date have attempted to consider whether facial pain is pre-attentively processed (Chiesa, Liuzza, Acciarino, and Aglioti, 2015; Chiesa, Liuzza, Macaluso, and Aglioti, 2017), both using the same basic design and materials and conducted by the same team. In the final section of this paper, we highlight these studies and reach a tentative conclusion about the strength of the available evidence for non-conscious facial pain detection.

Is Pain Privileged?

Why might one predict that facial expressions of pain — like anger or fear — would be recognizable to the visual system prior to, or otherwise without the need of, conscious awareness? According to Craig, Prkachin, and Grunau (1992), facial expressions of pain "function, above all, as social communications that convey distress and may recruit the help of others" (p. 153). Such a communicative act may have implications for survival and reproduction in at least two ways. First, if someone in one's visual field is in pain, presumably as a result of injury, this could signal the presence of an injury-causing stimulus (i.e., a threat) in the environment whose avoidance would be directly relevant to one's own fitness. And second, if the person happens to be a close relative, that is, shares a significant proportion of one's genes — as would be common in the EEA — then helping to quickly address the source of their pain could also indirectly increase one's fitness (Williams, 2002). Either way, it would be advantageous from an evolutionary perspective to recognize, as immediately as possible, that a conspecific was in pain, even if the person was not able to verbalize or even vocalize this fact for whatever reason (Earp et al., 2019). Being able to pre-attentively recognize facial expressions of pain would facilitate this, creating a strong selection pressure for development of the capacity.

On the other hand, one could argue that facial expressions of pain are less indicative of a direct threat to the observer than are fear or anger. For example, while displays of anger typically indicate a socially-oriented threat, pain-related behavior (including facial expressions) in both humans and non-human animals could also be a signal for the observer to exploit or predate (Williams, 2002). Consequently, the ability to suppress pain expression might carry a survival advantage as well and there is indeed empirical evidence that such expression is decreased in a threatening social environment (Karos et al., 2019; Peeters and Vlaeyen, 2011; Williams et al., 2016).

Thus, it is unclear based on these theoretical assumptions whether pain expressions would be processed pre-attentively. At this stage, there is some evidence that conscious awareness is not necessary to express pain via facial cues (Williams, 2002), but whether such awareness is necessary for perceiving or detecting pain expression in others is still an open question. As mentioned, only two studies to date have experimentally tested whether or not facial expression of pain is processed pre-attentively (Chiesa et al., 2015, 2017), both using similar materials, design elements, and procedures (apart from, for example, the addition of an fMRI component in the later study).[3] We will therefore evaluate the first study as a stand-in for both.

Study Evaluation

Chiesa et al. (2015) used a standard continuous flash suppression (CFS) technique combined with an affective misattribution procedure (AMP). Participants were presented, over 72 trials, with 24 randomly administered priming stimuli per condition representing three different categories: painful facial expression, pleasant facial expression, and neutral facial expression (all matched for brightness, contrast, and arousal) [see their Figure 1, on page 2375 of their manuscript]. The dynamic mask was made of neutral face images segmented into 128 x 128 pixel squares, randomly rearranged, and flashing at 10 Hz. For the AMP, participants had to judge whether a target Chinese pictogram was pleasant

[3] Terrighena, Lu, Yuen, Lee, and Keuper (2017) also evaluate subliminal processing of stimuli depicting or suggesting pain, but they do not use facial images, so their study is tangential to the main concern of this paper.

or unpleasant (forced choice). The authors found that the painful facial stimuli were associated with a significantly smaller percentage of "pleasant" pictogram judgments ($M = 48.6$, 95% CI [43.4, 53.8]) than either the neutral ($M = 55.9$, 95% CI [50.7, 61.1], $t(29) = -3.087$, $p = .013$, Cohen's $d = .52$) or pleasant (M = 58.8, 95% CI [53.9, 63.7], $t(29) = -4.464$, $p < .001$, Cohen's $d = .76$) stimuli.[4] They took this as evidence that facial expressions of pain *can* be detected without conscious awareness and influence target judgments in a congruent fashion (i.e., unpleasant affective attributions).

Several interesting points are raised by this study and its methodology. The AMP task usually involves either a positive or negative prime stimulus presented subliminally, i.e., for a duration that is typically too brief to induce conscious awareness (e.g., ≤ 30 ms), and which can at least in principle be individually-tailored to each participant's awareness threshold, as this may differ substantially from person to person (Pessoa, 2005).[5] In the current experiment, however, the authors chose *not* to use brief-duration subliminal priming, but rather CFS (as noted) because it allows the priming stimulus to be presented longer without entering conscious awareness.

A potential problem with this approach is that the masked image — which is openly and continually presented to one eye — can sometimes break through the attentional barrier, idiosyncratically for each participant, such that participants must self-report whether they saw the prime. As acknowledged by the authors, this approach does present certain limitations for demonstrating conclusively the existence of a capacity for detection-without-awareness with respect to a novel kind of stimulus. Indeed, of the 38 participants, fully 6 — more than 15% of the sample — had to be removed for reporting explicit awareness of the priming stimulus in *more than 25% of the trials* (Chiesa et al., 2015, p. 2377). This suggests that (1) many participants were frequently aware of the priming stimulus, and (2) an unknown number of participants who reported explicit awareness of the priming stimulus, albeit less than 25% of the time, would still have been included in the statistical analysis.

In order to address these issues, Chiesa et al. (2015) asked participants to report, for each trial, on which side of the fixation cross the suppressed stimulus was presented. According to Pessoa (2005), objective evidence for lack-of-awareness would be obtained if participants performed at chance on this task. However,

[4] The neutral and pleasant conditions did not differ from one another ($t(29) = -1.111$, $p = .827$, Cohen's $d = .20$).

[5] The prime is then followed by a neutral target image which participants must judge as being either positive or negative. If the neutral target is consistently judged to be, say, positively valanced when preceded by a positively valanced — but non-consciously-perceivable — priming stimulus, the thought is that the affective information encoded in the prime must have been picked up by the visual system (and misattributed to the target) despite not entering conscious awareness.

Chiesa et al. (2015) do not report this information. Rather, they state that the "percentage of correct responses in detecting the position of the prime provided an index of whether participants had implicitly detected the suppressed prime images, *differentially in the different conditions*" (p. 2377, emphasis added). Although an analysis of variance (ANOVA) did not show a statistically significant difference between conditions in terms of this index ($F(2,58) = .265, p = .768, \eta^2 = .009$), this does not necessarily mean that participants performed *at chance levels* for any of the conditions (Boyle, 2018). Thus, the "objective" criterion proposed by Pessoa (2005) may or may not have been met in this case.

As an additional approach to rule out the effects of explicit stimulus perception, Chiesa et al. (2015) used the linear regression method introduced by Greenwald, Klinger, and Schuh (1995). In this method, separate measures of direct (perceptual identification) and indirect (affective priming) effects of the stimulus are taken and entered into a regression. When measures of both effects have rational zero points — and all other assumptions of the model are met — a statistically significant intercept in the indirect-on-direct-measure regression implies that at least some amount of the indirect effect (the affective priming) occurred in the absence of the direct effect (the explicit perception of the stimulus). Consistent with this, Chiesa et al. (2015) found that the intercept term of the dependent variable was significantly greater than zero ($t(28) = 6.702, p < .001$). Thus, at least some of the priming effect seems to have occurred without explicit perception of the stimulus.

Let us grant, then, that there was a genuine MAP effect on the Chinese characters such that the "painful" face stimuli were indeed associated with a smaller percentage of positive target judgments. Still, we would have to ask if it is the painfulness of facial expression in that condition that was responsible for the priming effect, or some other feature of the stimulus from that condition. Looking at the sample stimuli in Figure 1 of Chiesa et al. (2015), at least one other feature apart from a pained facial expression stands out about the "painful" condition, namely the lack of symmetry in — and greater occlusion of — facial features caused by the compression of the slapping hand (especially apparent in the male model).[6]

With respect to lack of symmetry, this has been previously associated with more negative judgments concerning attractiveness (e.g., Perrett et al., 1998); hence it could be that relative unattractiveness, rather than detection of a painful expression per se, is what is driving the non-conscious priming effect (assuming it is a genuine effect). Better stimuli for a stricter test of the authors' hypothesis,

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[6] The example stimuli consist of a male and female face with a hand pressed against the model's left cheek. In the "painful" condition, the hand appears to be pressed with greater force, implying a slap at the moment of contact. In the "neutral" condition, the hand appears to be resting on the cheek, eliciting no particular facial expression. The "pleasant" condition appears similar to the neutral condition albeit with a smiling facial expression, implying a caress.

then, would involve faces with a pained, neutral, or pleasant facial expression — perhaps without a hand in the picture at all — with no other (e.g., orientation, symmetry, degree of occlusion) differences between conditions.

Conclusion

Is the visual system capable of registering painful facial expressions without the need for conscious awareness? In this paper, we have closely evaluated one of the only studies to date to address this question experimentally (Chiesa et al., 2015, 2017, focusing on the 2015 paper), finding both strengths and limitations. Although the study design was carefully conceived and executed, with several attempted methods for ruling out the possibility of conscious detection of the priming stimuli, we suggest that two main issues might be addressed for a more conclusive test of the hypothesis. First, the painful face stimuli would need to be more carefully matched with the neutral and pleasant face stimuli in terms of facial feature symmetry and facial occlusion; and second, only participants performing at chance levels on the "direct" spatial location task should be included in the statistical analyses.

We wish to make clear that our aim in this commentary has not been to criticize the findings of Chiesa and colleagues. Rather, our aim has been to position their fascinating results within a broader theoretical framework that seeks to clarify what is at stake in these kinds of experiments, while offering an analysis of particular design features which we think could be strengthened in this area going forward. Altogether, we find that there are partial or mixed theoretical bases to predict that facial expressions of pain are processed without conscious awareness, and that the empirical support for this prediction remains promising but preliminary. Further exploration of this research question, we suggest, could have implications for our understanding of pain as not only an intra-personal, but also an inter-personal, signal of threat (Vervoort et al., 2018).

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