

Preference Is Biased by Crowded Facial Expressions

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Abstract

Crowding occurs when nearby flankers impede the identification of a peripheral stimulus. Here, we studied whether crowded features containing inaccessible emotional information can nevertheless affect preference judgments. We relied on gaze-contingent crowding, a novel method allowing for constant perceptual unawareness through eye-tracking control, and we found that crowded facial expressions can bias evaluative judgments of neutral pictographs. Furthermore, this emotional bias was effective not only for static images of faces, but also for videos displaying dynamic facial expressions. In addition to showing an alternative approach for probing nonconscious cognition, this study reveals that crowded information, instead of being fully suppressed, can have important influences on decisions.

Keywords

nonconscious perception, crowding, face processing, emotions

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The human eye constantly receives signals from the environment, yet people are aware of only a limited quantity of visual information. Indeed, a large part of the visual field is susceptible to the crowding phenomenon, in which peripheral objects appear jumbled when surrounded by similar neighbors. Crowding is commonly attributed to feature integration of the object and its flankers in an inappropriately large region, called an *integration field* (Levi, 2008; Pelli & Tillman, 2008). As a consequence, peripheral objects are no longer discriminable and give the impression of a texturelike percept. However, it remains unclear whether crowded stimuli are suppressed very early in the visual system (Pelli, 2008) or at later levels of processing (Intriligator & Cavanagh, 2001). If the latter, one might expect crowded objects to be encoded and maintained in the visual system despite unawareness and to eventually influence human behaviors in a nonconscious manner.

Numerous studies have investigated the crowding of face stimuli, focusing primarily on the mechanism underlying the elimination of perceptual awareness. This research has revealed that crowding can occur selectively between high-level, configurational representations of faces (Farzin, Rivera, & Whitney, 2009; Louie, Bressler, & Whitney, 2007) and that statistical information can be rapidly extracted from crowded faces (Haberma & Whitney, 2007). Yet research has largely neglected the extent to which crowded contents are still processed in the absence of perceptual awareness. A few notable exceptions are studies showing that low-level features (i.e.,

line orientations) are preserved despite crowding and can induce visual adaptation (He, Cavanagh, & Intriligator, 1996). Whether crowded stimuli induce nonconscious influences at higher, nonperceptual levels (e.g., dealing with emotional or semantic content) is undetermined.

The majority of research on nonconscious perception has relied on visual masking (Kouider & Dehaene, 2007; Marcel, 1983). For example, researchers found that brain regions dealing with emotional information are activated even when fearful faces are presented very briefly (i.e., for less than 50 ms) and backward-masked, presumably in the absence of awareness (e.g., Whalen et al., 1998). However, such findings have proven difficult to replicate when visibility is stringently controlled (Pessoa, 2005; Pessoa, Japee, Sturman, & Ungerleider, 2006). The fragility of subliminal influences in masking paradigms has been related to the strong degradation of visual signals, to prevent awareness. Indeed, because masking disrupts the efficient propagation of bottom-up activation in successive perceptual areas, subliminal influences are expected to decrease with synaptic distance, becoming small or undetectable in distant brain regions dealing with high-level information (Kouider & Dehaene, 2007).

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Another recent method for studying nonconscious perception is continuous flash suppression (CFS; Fang & He, 2005; Tsuchiya & Koch, 2005), an extension of binocular rivalry that consists of presenting one eye with a dynamic stream of contour-rich, high-contrast patterns in order to suppress from awareness the prime stimulus in the other eye. This method has the advantage of allowing for long stimulus durations, thus potentially increasing the strength of subliminal signals. However, in CFS, the largest suppression appears to occur relatively early in the visual system, impeding processing in higher visual regions of the ventral stream dealing with object and face recognition (Lin & He, 2009). It has recently been shown, using CFS, that although categorically congruent suppressed primes can facilitate the categorization of tools (assumed to be processed in the dorsal visual pathway), these primes have no effect on the categorization of nonmanipulable objects (assumed to be processed in the ventral visual pathway; Almeida, Mahon, Nakayama, & Caramazza, 2008).¹ In sum, although it is well documented that nonconscious perception involves low-level, sensorimotor pathways, evidence for influences at higher (e.g., emotional, semantic) levels remains scarce and is sometimes difficult to replicate (for reviews, see Kouider & Dehaene, 2007, on visual masking and Lin & He, 2009, on CFS).

One possibility is that the observed weakness of subliminal influences reflects methodological rather than theoretical limitations. Methods consisting of bombarding one eye with

flashes, as in CFS, or of masking a stimulus presented for only a few 10s of milliseconds, are likely to be confined to laboratory contexts. By contrast, crowding might constitute an interesting alternative approach because it occurs naturally and frequently in the perceptual environment. Furthermore, the human brain might even have been optimally tuned for processing certain peripheral stimuli (e.g., as part of danger avoidance). In this study, we investigated whether crowded faces expressing strong emotional content (happiness vs. anger) can influence preference judgments of neutral stimuli. Unlike masking and CFS, crowding does not impede stimulus detection. However, it is important to remember that some aspects of the crowded stimulus (e.g., emotional content) might remain nondiscriminable under certain conditions.

One main difficulty with manipulating peripheral contents is that stimuli conveying salient information (e.g., strong emotional information) naturally attract attention and foveal focus. To overcome this problem, we developed an approach termed *gaze-contingent crowding* (GCC), which consists of presenting long-lasting (i.e., 2,500 ms) peripheral stimuli that are crowded by surrounding flankers while precluding foveal access through high-resolution eye tracking (see Fig. 1). The gaze-contingent control consisted of substituting the crowded stimulus with irrelevant content as soon as the observer's gaze diverged from an arbitrary fixation location. Thus, the method reliably prevented conscious access to the emotional content of the stimulus. This approach allowed us to determine whether

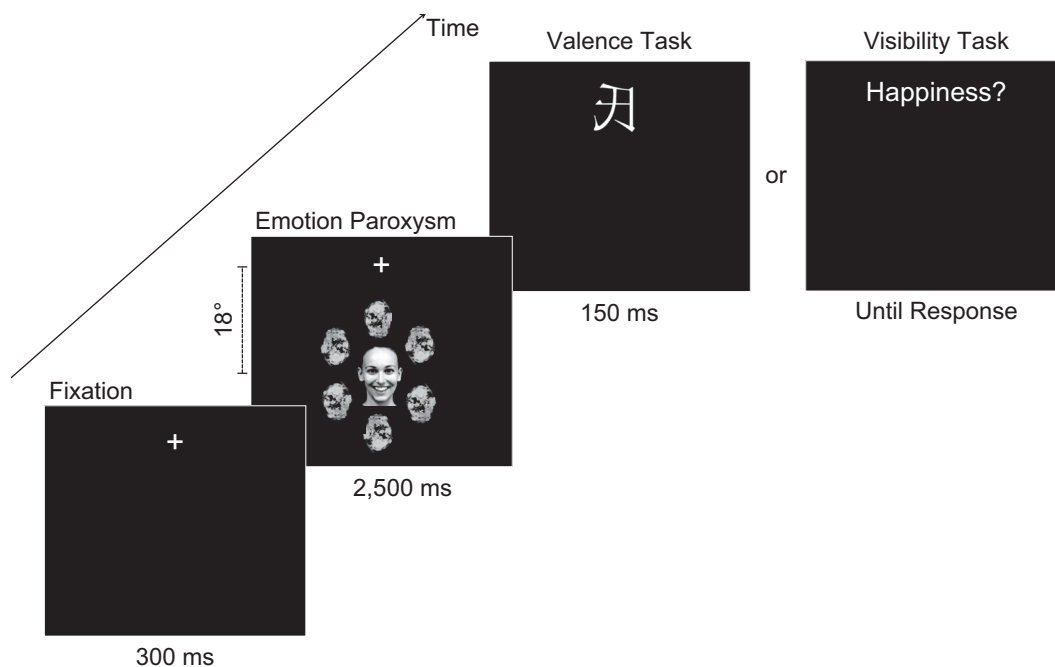


Fig. 1. Illustration of the gaze-contingent crowding procedure. Each trial consisted of the presentation of a fixation cross, followed by a peripheral emotional face surrounded by flankers. The emotional face was replaced by the same face with a neutral expression as soon as the participant ceased to gaze at the fixation cross. This event was followed, randomly, either by a Chinese pictograph (valence task) or by the question “anger?” or “happiness?” (referring to the emotion of the prime; visibility task). Participants made evaluative judgments (pleasant/unpleasant) on pictographs (measure of prime influence) and answered “yes” or “no” to the questions (i.e., reported whether or not the prime expressed the indicated emotion; measure of prime discrimination). Depending on condition, the prime faces were static or dynamic.

crowded faces, presented not only statically but also dynamically (i.e., like movie sequences) can bias preference judgments in a nonconscious manner.

Method

Participants

A total of 79 French college students (age range = 18–35 years) participated in the study. They were paid €10 for their participation. All had normal or corrected-to-normal vision and were unable to read Chinese.

Stimuli and procedure

Participants sat 57 cm from a computer screen. On each trial, they stared at a $0.5^\circ \times 0.5^\circ$ fixation cross while the prime face ($3.2^\circ \times 3.9^\circ$) was displayed either statically or dynamically for 2,500 ms (18° center-to-center eccentricity between face and cross). The prime face was surrounded by six noninformative pattern flankers ($2.5^\circ \times 2.8^\circ$; 3.1° center-to-center eccentricity between face and flankers). Whenever a participant ceased to gaze at a $5^\circ \times 5^\circ$ invisible zone around fixation, the face was replaced by the same face with a neutral expression (with a maximum delay of two screen refreshes). This procedure guaranteed that the emotional information in the face was never accessed foveally. Then, at the fixation location, either (a) an unknown Chinese pictograph ($3^\circ \times 3^\circ$) or (b) the question “anger?” or “happiness?” was presented. The pictograph was displayed for 150 ms, and participants were expected to indicate whether or not it was pleasant (measure of prime influence; 120 trials); the word question was displayed until the participant indicated whether or not the word corresponded to the facial expression of the prime (measure of prime discrimination; 60 trials). The two kinds of trials were intermixed randomly, so participants could not predict their task on a given trial. Processing during the prime presentation was thus identical under both conditions. Prime valence (i.e., happiness or anger) was manipulated within participants, and prime type (i.e., static or dynamic) between participants.

Prime stimuli were obtained by videotaping five professional actresses demonstrating dynamic expressions of happiness and anger. Videos were speeded up or down slightly to compensate for differences in timing between the different actors' expressions. Each video started with a neutral expression (500 ms), followed by emotional progression until paroxysm (1,000 ms), and finally dynamic maintenance at the peak level (1,000 ms). Static faces were extracted from each movie; neutral expressions were taken from the 0-ms point in the videos, and emotional-paroxysm expressions were taken from the 1,500-ms point. Stimuli were matched for average luminance, contrast, size, and (for movies) timing of expression progression. The flankers were noninformative patterns created by overlaying faces and objects (de Gardelle & Kouider, 2010). Their luminance was 40% higher than that of the primes. The

display was controlled by the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997). Stimuli were presented against a black background (0.004 cd/m^2) on a 22-in. screen (frame rate: 85 Hz; resolution: $1,024 \times 768$ pixels). Eye movements were recorded monocularly with a tower-mounted eye tracker (Eyelink 1000 system, SR Research, Mississauga, Ontario, Canada; sampling rate: 1000 Hz; spatial resolution: $\geq 1^\circ$).

Results

Target pictographs were evaluated as pleasant at a mean rate of 55.7% ($SD = 9.5\%$). Crucially, evaluation of the pictographs was significantly modulated by prime valence; the rate at which the pictographs were judged pleasant was 6.8% higher following happy faces than following angry faces, $F(1, 41) = 9.08$, $p < .005$ (see Fig. 2). The interaction between prime valence and prime type was not significant, $F < 1$, as the magnitude of the bias was equivalent for static primes (6.7%), $t(21) = 2.17$, $p < .05$, and dynamic primes (7.0%), $t(20) = 2.10$, $p < .05$. Debriefing after the experiment revealed that none of the participants could detect the emotion expressed by the crowded faces. Signal detection analysis on the prime-discrimination trials revealed chance-level performance both for static primes (mean $d' = 0.02$), $t(21) = 0.21$, $p = .84$, and for dynamic primes (mean $d' = 0.18$), $t(20) = 1.57$, $p = .13$, confirming that GCC successfully prevented access to emotional information in the periphery. It is noteworthy that although participants complied with the instructions in a majority of trials, they also attempted to stare specifically at the prime on 9.5% ($SD = 7.0\%$) of the trials (1.7%, $SD = 1.4\%$, of total fixation time; see Fig. S1 in the Supplemental Material available online). This tendency was constant across the whole protocol, which suggests that gaze-contingent control is a crucial manipulation for preventing the identification of peripheral stimuli.

Although the stimuli were matched for low-level properties on several dimensions, one possible reason for the effect of prime valence might be that there were still systematic, unaccounted-for differences between the stimuli displaying angry and happy faces. In order to rule out this possibility, we conducted an additional, control experiment using the same procedure, design, and materials as before, except that the faces were presented as upside-down images and upside-down videos. In these conditions, participants' evaluations of the pictographs were not influenced by prime valence (0.4% difference for static stimuli and -1.01% difference for dynamic stimuli, both $F_s < 1$). Thus, the decision bias observed with upright faces reflects a genuine extraction of emotional information from them.

Discussion

In this study, we used a new method, GCC, that allows for the long-lasting presentation of nonconscious visual signals in the periphery. We found that a crowded stimulus conveying

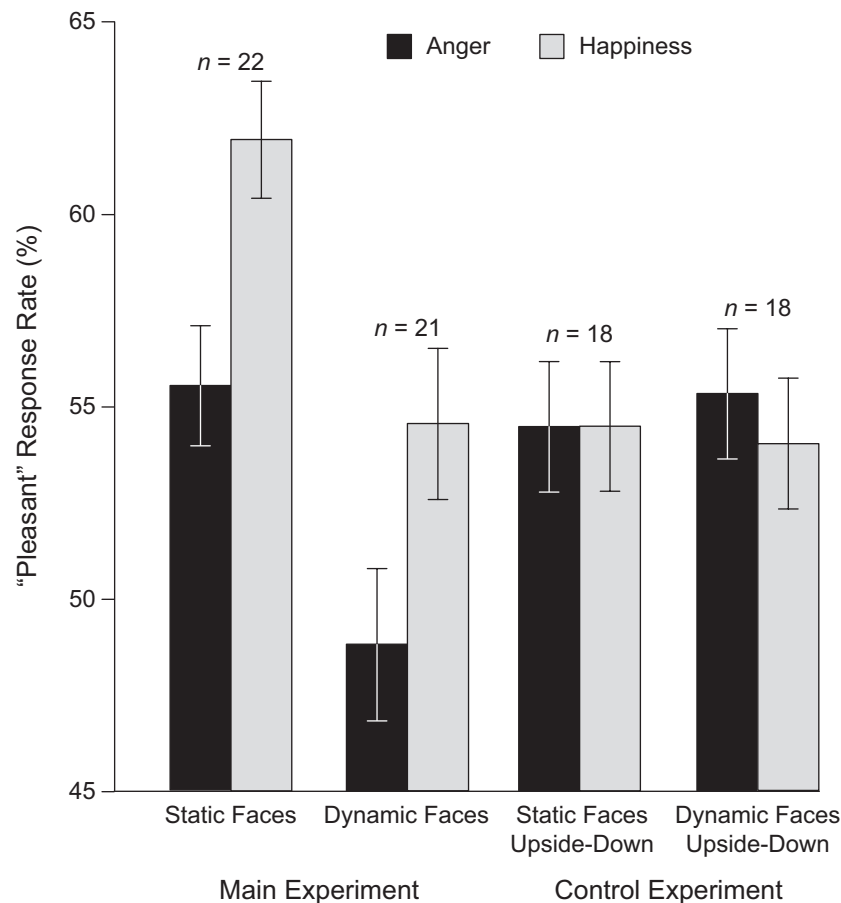


Fig. 2. Mean percentage of unknown Chinese pictographs judged as pleasant in the main experiment (upright faces) and the control experiment (upside-down faces). Percentages are shown as a function of prime type (static or dynamic) and prime valence (anger or happiness). Error bars denote 1 SE. The number of participants tested in each condition is shown.

emotional information can bias evaluative judgment of a neutral, unknown target. Furthermore, this nonconscious emotional influence was not exerted when the crowded faces were inverted, a result confirming that the emotional effect we observed has a configurational, rather than featural, origin. These results have several implications.

One implication concerns the phenomenon of crowding itself. Crowding occurs when the features of an object and its flankers are integrated into the same integration field, which results in a jumbled percept in which the object cannot be discriminated. It is agreed that the size of the integration field increases with eccentricity, but the origin of this widening is debated. According to bottom-up proposals, integration fields are materialized in primary visual cortex (Pelli, 2008). This hardwired limitation would imply a loss of information for crowded stimuli at and beyond V1. According to top-down proposals, the size of the integration field is the size of the spotlight of attention (Intriligator & Cavanagh, 2001), which suggests that crowded information is present in the visual system but remains inaccessible because of inattention. Our results extend these findings by showing that crowded

emotional features that cannot be discriminated are preserved and are able to bias behaviors.

One might still argue for a bottom-up account, according to which the emotional effect we observed reflects subcortical processing of faces, bypassing cortical pathways. Indeed, LeDoux (1998) described two alternative cerebral routes for emotion processing: the thalamo-amygdala pathway (*short route*) and the thalamo-cortico-amygdala pathway (*long route*). Studies with blindsight patients suggest that, instead of engaging ventral (i.e., occipito-temporal) pathways in the visual cortex, perception of emotions engages alternative subcortical regions such as the superior colliculus and the pulvinar, which are connected to the amygdala without any cortical relay (de Gelder, Vroomen, Pourtois, & Weiskrantz, 1999). However, strong evidence for the existence of connections between the amygdala and the pulvinar in humans is still lacking (Pessoa, 2005). Furthermore, stimulus processing in the suppressed hemifield of blindsight patients has also been correlated not only with subcortical regions but also with cortical visual regions (e.g., MT+, lateral occipital complex) that are probably engaged as a result of residual V1 activity (Goebel, Muckli, Zanella, Singer, &

Stoerig, 2001). These cortical regions could then elicit the amygdala, and amygdala activity would then be falsely interpreted as being due to processing by the short route. Furthermore, a patient with complete bilateral lesions in the amygdala has been reported to process subliminal fearful stimuli without notable differences from normal participants (Tsuchiya, Moradi, Felsen, Yamazaki, & Adolphs, 2009), which suggests that the amygdala is not necessary for nonconscious, rapid fear detection, but rather plays a belated role (once cortical processing has taken place) in face representation, modulation of social judgments, and other higher-order cognitive processes.

It is important to note that we found that inverted crowded faces were not processed as emotional stimuli. Recently, it has been debated whether the differences between the processing of upright faces and the processing of inverted faces are quantitative or qualitative (Sekuler, Gaspar, Gold, & Bennett, 2004). In any case, physiological measures indicate that these differences arise from cortical regions along the ventral visual pathways, such as the fusiform face area (Kanwisher & Yovel, 2006). Thus, it is tempting to consider our result as evidence for the nonconscious maintenance of crowded information in cortical areas beyond V1 (Greenwood, Bex, & Dakin, 2010; Parkes, Lund, Angelucci, Solomon, & Morgan, 2001).

We found that GCC could be used to demonstrate influences from both static pictures and videos. However, we did not observe greater emotional effects for dynamic stimuli than for static stimuli, although such a difference is usually found for visible faces (Trautmann, Fehr, & Herrmann, 2009). The fact that we did not observe the same pattern as for visible faces has important implications regarding the limits of nonconscious processing, as the possibility of sequential processing without awareness remains an important but unsettled question. One possibility is that a processing advantage for dynamic stimuli occurs only during the conscious perception of emotional content. Future experiments examining the differential processing of crowded and uncrowded (i.e., discriminable) stimuli might be necessary to shed light on this issue. If the processing advantage for dynamic stimuli is restricted to uncrowded displays, that would suggest that crowded movies are not processed as dynamic stimuli per se and are thus not integrated across time. Alternatively, it remains possible that the evaluative judgments we elicited in our experiment were not sensitive enough to the static/dynamic manipulation. In that case, investigating the neural response associated with the processing of crowded dynamic and static displays may be useful in investigating the possibility of nonconscious temporal integration.

Finally, regarding the phenomenology of crowding, it is important to point out that crowding constitutes a prototypical situation of partial awareness (Kouider, de Gardelle, Sackur, & Dupoux, 2010) in which the stimulus is perceived as a jumbled object because restricted levels of processing are consciously accessed while most others remain below the threshold of consciousness. Although participants in our experiment could detect the presence of a crowded stimulus (as a texturelike pattern), the stimulus features that were

diagnostic for priming effects (emotional attributes) were impossible to discriminate and therefore had nonconscious influences on responses relying on that particular type of information. Together, these results suggest that although crowding constitutes a bottleneck in object recognition, limiting conscious access when there is an overflow of visual signals, it spares the environmental information that is necessary for nonconscious behavioral responses.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Supplemental Material

Additional supporting information may be found at <http://pss.sagepub.com/content/by/supplemental-data>

Note

1. In addition, CFS poses practical problems for preventing awareness constantly during an experiment, because suppression can be broken at any moment when participants just close one eye.

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