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Learning to fear depends on emotion and gaze interaction: The role of self-relevance in fear learning

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ABSTRACT

Emotional learning is an adaptive function, however its psychological determinants are unclear. Here, we propose a new theoretical framework based on appraisal theories of emotion, which holds that emotional learning is modulated by a process of relevance detection. Testing the model, we predicted faster, larger acquisition and greater resistance to extinction of the conditioned response (CR) to self-relevant stimuli relative to stimuli with less relevance. We manipulated self-relevance through emotion and gaze direction of synthetic dynamic facial expressions during differential aversive conditioning. Results provided mixed evidence for our hypotheses. Critically, we revealed faster acquisition of the CR to angry faces with direct compared with averted gaze and greater resistance to extinction to fearful faces with averted relative to direct gaze. We conclude that the relevance detection hypothesis offers an appropriate theoretical framework allowing to (re)interpret existing evidence, incorporate our results, and propose a new research perspective in the study of emotional learning.

1. Introduction

Emotional learning refers to the process by which a stimulus acquires an emotional significance. It represents a crucial adaptive function enabling an organism to respond appropriately to environmental stimuli by learning to identify their aversive or appetitive characteristics. Although neural mechanisms of emotional learning have been widely studied (see Phelps, 2006), psychological determinants underpinning the attribution of emotional value to stimuli, situations, events or behaviors remain unclear.

According to Seligman's (1970, 1971) preparedness theory, organisms are prepared to develop fear reactions to specific threatening stimuli based on biological predispositions shaped by the evolution of the species. The concept of preparedness has received strong empirical support demonstrating faster (e.g., Ho & Lipp, 2014; Öhman, Eriksson, & Olofsson, 1975) and larger (e.g., Fredrikson, Öhman, & Hugdahl, 1976; Öhman, Fredrikson, & Hugdahl, 1978) acquisition of a fear response to evolutionary fear-relevant stimuli than to fear-irrelevant stimuli. More importantly, critical evidence supporting the preparedness theory is the resistance to extinction of learned fear to fear-relevant stimuli from phylogenetic origin, such as snakes (e.g., Öhman et al., 1975; Öhman, Fredrikson, Hugdahl, & Rimmö, 1976) and angry faces (e.g., Öhman & Dimberg, 1978), whereas extinction occurs rapidly for fear-irrelevant stimuli, such as flowers and happy faces (for a review, see Öhman & Mineka, 2001). Other studies showed that the learned fear response to phylogenetically fear-relevant stimuli was resistant to extinction even without awareness of these stimuli (e.g., Esteves, Parra, Dimberg, & Öhman, 1994; Öhman & Soares, 1993; for a review, see Öhman & Mineka, 2001). In a related line of research, Öhman and colleagues (Öhman, Flykt, & Esteves, 2001; Öhman, Lundqvist, & Esteves, 2001) showed that evolutionary relevant threatening stimuli automatically captured attention. Integrating these empirical findings with preparedness theory, Öhman and Mineka (2001) proposed the existence of an evolved fear module implemented in the human brain to explain the initiation and learning of fear, positing in particular that threatening stimuli encountered by the species during their evolutionary past benefit from enhanced learning compared with threatening stimuli from ontogenetic origin or non-threatening stimuli.

However, several empirical results have contradicted the hypothesized superiority of phylogenetically fear-relevant stimuli relative to ontogenetically fear-relevant stimuli. For instance, Hugdahl and Johnsen (1989) showed that resistance to extinction for gun pictures pointed toward the participants (i.e., a cultural

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threat) associated with a loud noise was not statistically different from resistance to extinction for snake pictures directed toward the participants (i.e., a biological threat) associated with electrical shocks. Flykt, Esteves, and Öhman (2007) reported resistance to extinction for masked presentation of snake and gun pictures only when they were directed toward the participants, but not when they were directed away from the participants. These findings are consistent with the existence of a similar conditioning effect for biological and cultural threats. Similar results were also reported regarding attention processes. For instance, Brosch and Sharma (2005) showed that threatening stimuli from phylogenetic origin were not detected faster or more easily than threatening stimuli from ontogenetic origin in visual search. Jointly, these empirical data suggest, critically, that the key factor influencing fear learning seems to be fear-relevance rather than evolutionary history.

In line with this suggestion, appraisal theories of emotion may offer a different view, proposing that fear-relevant stimuli benefit from enhanced learning not because they are associated to fear through evolution, but because they are highly relevant for the individual (see Sander, Grafman, & Zalla, 2003). From this perspective, fear-relevant stimuli from phylogenetic origin are likely to be detected and automatically appraised as highly relevant to the organism's survival, which could account for the preferential allocation of attentional resources and enhanced fear learning to these stimuli. However, the process of relevance detection is not thought to differ for fear-relevant stimuli from phylogenetic and ontogenetic origin, respectively, or even as compared with relevant positive stimuli. Indeed, appraisal theories predict that highly relevant stimuli are prioritized in attentional processing, better learned and memorized regardless of their valence and evolutionary status per se (see Sander, Grandjean, & Scherer, 2005). Several studies have shown that attention (Brosch, Sander, Pourtois, & Scherer, 2008; Brosch, Sander, & Scherer, 2007; Pool, Brosch, Delplanque, & Sander, 2014) and memory (Montagrin, Brosch, & Sander, 2013) processes are specifically modulated on the basis of the affective relevance of the stimulus events. In particular, Brosch et al. (2008) demonstrated that spatial attention orienting processes were modulated equally strongly by angry adult faces and by baby faces, both at the behavioral and the neural level, indicating that relevant threatening and relevant positive stimuli benefited from a similar prioritization.

Taken together, these observations support no special status of fear-relevant stimuli from phylogenetic origin as compared with fear-relevant stimuli from ontogenetic origin and relevant positive stimuli. More importantly, they suggest that the preferential learning of "evolutionarily prepared" threat stimuli, such as snakes and angry faces, could be due to a more general mechanism of relevance detection rather than biological preparedness. To the best of our knowledge, no research has, however, directly investigated the role of relevance detection in emotional learning.

The purpose of this research was thus to make a first contribution to the study of relevance detection as a determinant of emotional learning. In this perspective, we investigated the impact of self-relevance on fear learning by manipulating the interaction between emotion and gaze in facial expressions (see Cristinzio, N'Diaye, Seeck, Vuilleumier, & Sander, 2010; N'Diaye, Sander, & Vuilleumier, 2009; Sander, Grandjean, Kaiser, Wehrle, & Scherer, 2007). According to appraisal theories, the processing of gaze direction modulates the detection and appraisal of self-relevance of a facial expression (Sander et al., 2003, 2007). Consistent with this perspective, previous work has shown the importance of the direction of facial and gaze display both in conditioning (Dimberg & Öhman, 1983) and attention (e.g., Juth, Lundqvist, Karlsson, & Öhman, 2005) to threat. For instance, Dimberg and Öhman (1983) reported resistance to extinction of conditioned fear to directed (i.e., head and eyes directed toward the participants) angry faces but not to averted angry faces. The study by Juth et al. (2005) showed that directed faces were consistently detected more quickly and accurately than averted faces, both for angry and fearful expressions. In discrepancy with the results of Juth et al. (2005), appraisal theories posit, however, that a facial expression of anger is more self-relevant with direct gaze relative to averted gaze because it signals danger of being attacked, whereas a facial expression of fear is more self-relevant with averted gaze, since it signals a danger in the proximal environment (Sander et al., 2003). Building on these predictions and previous evidence of superior conditioning to fear-relevant stimuli as compared with fear-irrelevant stimuli (see Öhman & Mineka, 2001), we propose that – if a relevance detection mechanism is involved in fear learning – highly self-relevant stimuli should hence lead to the acquisition of a conditioned fear response that is more rapidly and largely acquired, and that is more resistant to extinction than stimuli with less relevance.

To test this hypothesis, we presented synthetic dynamic facial expressions to participants by manipulating self-relevance through emotion and gaze interaction in a differential aversive conditioning paradigm. We hypothesized that (a) angry faces with direct gaze compared with averted gaze and (b) fearful faces with averted gaze relative to direct gaze would lead to (1) a faster acquisition of the conditioned fear response, (2) the acquisition of a larger conditioned response, and (3) an enhanced resistance to extinction of the conditioned response.

2. Method

2.1. Participants

Ninety-three undergraduate students from the University of Geneva participated in the experiment for course credit and provided informed consent. Twelve participants were excluded from conditioning analysis due to technical problems, seven for displaying virtually no skin conductance responses, and 13 because of failure to acquire a conditioned response to at least one of the two conditioned stimuli positively predictive of the unconditioned stimulus. The exclusion criteria applied are widely accepted in the human conditioning literature (e.g., Olsson, Ebert, Banaji, & Phelps, 2005). The final sample included 61 students (12 men) aged between 18 and 42 years ($M = 21.59$, $SD = 3.52$).

2.2. Stimuli and apparatus

Four synthetic dynamic facial expressions[1] (two of anger and two of fear) either with direct gaze or averted gaze served as conditioned stimuli (CS). Dynamic expressions were created from four male identities of the Radboud Faces Database (Langner et al., 2010) using FACSGen (see Krumhuber, Tamarit, Roesch, & Scherer, 2012; Mumenthaler & Sander, 2015; Roesch et al., 2011). The same four face identities were presented to all participants. Each face identity served both as positively conditioned stimulus (CS+) and negatively conditioned stimulus (CS−), counterbalanced across participants. The stimuli were presented using MATLAB (The MathWorks, Inc., Natick, Massachusetts) with the Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997) and MATLAB Compiler Runtime. The unconditioned stimulus (US) was an electric stimulation (200-ms duration, 50 pulses/s) delivered to the right wrist through a Grass

[1] We used synthetic dynamic stimuli in order to increase ecological validity – emotional facial expressions and gaze shifts being dynamic in nature – while being able to perform highly controlled manipulations of (a) the time course of eye movements and unfolding of dynamic facial expressions, and (b) action units implied in the expressions and their intensity.