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Spontaneous eye movements and trait empathy predict vicarious learning of fear

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ABSTRACT

Learning to predict dangerous outcomes is important to survival. In humans, this kind of learning is often transmitted through the observation of others' emotional responses. We analyzed eye movements during an observational/vicarious fear learning procedure, in which healthy participants ($N = 33$) watched another individual ('learning model') receiving aversive treatment (shocks) paired with a predictive conditioned stimulus (CS+), but not a control stimulus (CS−). Participants' gaze pattern towards the model differentiated as a function of whether the CS was predictive or not of a shock to the model. Consistent with our hypothesis that the face of a conspecific in distress can act as an unconditioned stimulus (US), we found that the total fixation time at a learning model's face increased when the CS+ was shown. Furthermore, we found that the total fixation time at the CS+ during learning predicted participants' conditioned responses (CRs) at a later test in the absence of the model. We also demonstrated that trait empathy was associated with stronger CRs, and that autistic traits were positively related to autonomic reactions to watching the model receiving the aversive treatment. Our results have implications for both healthy and dysfunctional socio-emotional learning.

1. Introduction

Learning to predict dangerous outcomes is important to survival. To understand the mechanisms underlying this learning, past research has focused the study on direct, Pavlovian, fear conditioning (LeDoux, 2012). In a fear conditioning procedure, a conditioned stimulus (CS+) is repeatedly paired with a naturally aversive unconditioned stimulus (US), such as an electric shock. The US elicits an unconditioned response (UR), which can take the form of behavioral avoidance or increased autonomic arousal. After repeated CS–US pairings, the CS will elicit a conditioned response (CR) similar to the UR.

In our socio-cultural environment, information about what is dangerous and should be avoided is commonly transmitted through other individuals by verbal communication and observation (Goubert et al., 2011; Olsson and Phelps, 2007; Rachman, 1977. This is often adaptive, because social or vicarious learning can be more effective and less dangerous than learning from individual trial and error (Rendell et al., 2010). Social transmission of fear can, however, also cause exaggerated and dysfunctional fear and anxiety, which is reflected by the inclusion of social transmission of fears and anxieties in the most recent Diagnostic and Statistical Manual of Mental Disorders (DSM 5; *American Psychiatric Association*, 2013). Previous research has shown that Pavlovian fear conditioning involves a network of brain regions, critically including the amygdala, which serves to enhance attentional allocation to the emotionally significant stimuli, and to shape CS–US associations and the ensuing CR (LeDoux, 2012; Phelps and LeDoux, 2005). In spite of a growing scientific interest in social or vicarious learning of fear in humans (Helsen et al., 2013; Olsson and Phelps, 2007) and non-human animals (Debiec and Sullivan, 2014; Jeon et al., 2010), the processes underlying the social transmission of fear remain largely unknown.

Recently, research has provided evidence that vicarious and Pavlovian fear learning is relying on partly overlapping biological mechanisms (Askew and Field, 2007; Olsson and Phelps, 2004, 2007). Accordingly, the observed individual's (the 'learning model's') expression of fear or distress can serve as a 'social' US affecting the learning through processing of social information in analogy to how tactile-sensory qualities of a Pavlovian US affect learning in direct fear conditioning. In support of this, a classical study by Mineka et al. (1984) showed that the UR–CR relationship in vicarious and Pavlovian fear learning is similar. This study demonstrated that the level of distress displayed by a model rhesus monkey in the presence of a snake was highly predictive of the subsequent level of learned fear as expressed by an observing monkey.

Vicarious fear learning should also be dependent on a range of social and cognitive factors, such as attention to salient cues in the environment that are informative of the occurrence and quality of the social US. In support of this, past research has shown that learning from others' emotional

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expressions of distress depends on the learner's perception of, and expectations about, the model, as well as the US. In an early study, Berger (1962) demonstrated that human participants acquired a CR by watching a confederate taking part in an alleged Pavlovian conditioning procedure. This, and another similar study (Hygge and Öhman, 1978), both demonstrated that the more salient the expression of the model, and the stronger the belief that the shocks were real, the stronger was the subsequent CR. These results are consistent with the finding that social learning of fear is also possible through verbal transmission alone, for example, when a person is explicitly told that a stimulus is predictive of an aversive outcome (Olsson and Phelps, 2004; Phelps et al., 2001).

Subsequent studies in humans and other species have pointed to a number of additional factors that may influence vicarious fear learning (Goubert et al., 2011). These include situation specific factors, such as tonic arousal level (Bandura and Rosenthal, 1966), empathic appraisal (Olsson et al., submitted for publication), perceived qualities of the model, such as perceived similarity (Golkar et al., 2015), and emotional expressiveness of (Goubert et al., 2011), as well as the fear-relevance of the CS (Askew and Field, 2007). Providing further clues about the underlying mechanisms, a fMRI study on vicarious fear learning (Olsson et al., 2007) showed activity in brain regions implicated in Pavlovian fear conditioning (i.e., the amygdala), as well as empathic processes (the anterior cingulate cortex, and anterior insula, Bernhardt and Singer, 2012). Importantly, activity in these regions during observation of the model's expressions when receiving shocks, predicted the strength of the CR as expressed at a later time in the absence of the model.

In accordance with the research reviewed here, attention to the learning model's emotional expressions, including facial and bodily movements, and their contingent occurrence with CS, should determine the efficiency of fear learning from vicarious experiences.

1.1. Eye-movements in emotional processing

A long line of research has documented that humans tend to direct a larger proportion of their fixations to socially and emotionally significant parts of naturalistic social scenes (Findlay and Gilchrist, 2003). Furthermore, eye movements during visual scene perception do not only reflect the actual content of the scene, but are also used to encode predictions about the actions of observed agents (Falck-Ytter et al., 2006). Analyses of eye movements can therefore be informative about how a visual scene is processed. The threat-relevance and emotional salience of visual stimuli is typically reflected in the pattern of eye movements. For example, humans fixate longer on fearful or angry faces than neutral (Green et al., 2003; Hunnius et al., 2011), make more and longer fixations towards emotionally laden scenes (Nummenmaa et al., 2006). Eippert et al. (2012) recently demonstrated that this finding extends to CS+ after Pavlovian fear conditioning. In line with this, we expected that fear learning would affect participants' gaze behavior.

The human face is a rich source of information about both mental states and the external world. The direction of another individual's gaze can effectively trigger shifts of attention to a new location. This indicates that humans follow the gaze of others to retrieve potentially important information from the surrounding environment. This is believed to constitute an important mechanism for social learning (Meltzoff et al., 2009; Tomasello, 2009). Eye movements are also likely to be important for successful recognition of facial emotion and facial memory (Henderson et al., 2005). Therefore, it is not surprising that fearful expressions in conspecifics have been shown to influence associative learning in both human and other primates (Blair, 2003; Meffert et al., 2014; Mineka and Cook, 1993; Olsson and Phelps, 2007). Given the importance of attention to human faces in social learning, we expected that participants' attention to the model's face would increase in the presence of a CS+ predictive of vicarious shocks, and that longer fixation time at the model's face would result in stronger learning.

1.2. Empathic processes and autistic traits

Autism spectrum disorder (ASD) is a neurodevelopmental condition characterized by impaired social interaction and understanding. Autistic traits are normally distributed in the population (Ronald and Hoekstra, 2011), and individuals with higher degrees of subclinical autistic traits may show some of the social cognitive characteristics of ASD (e.g. Dalton et al., 2007). One of the most studied social impairments in ASD is atypical attention to faces (Guillon et al., 2014). For example, adults with ASD are less likely than typically developed persons to direct their gaze towards the eyes of others in complex social scenes (Klin et al., 2002). Given the importance of attention to faces for efficient social learning, ASD or autistic traits would be expected to be linked to attenuated social learning of fear. Somewhat unexpectedly, subclinical autistic traits have recently been linked to stronger vicarious fear learning. Miu et al. (2012) compared fear learning in nonclinical groups with either high or low self-reported autistic traits using an observational fear learning paradigm adapted from Olsson et al. (2007). Interestingly, the participants with high autistic traits showed a stronger CR, which is surprising if the appraisal of the model's mental state is important for the ensuing learning, and the fact that autistic traits are associated with lower levels of trait empathy (Lawrence et al., 2004). The results by Miu et al. might, however, be explained by strong vicarious responses. In fact, there is evidence that individuals with ASD show at least as strong autonomic responses, and experience distress in response to distress in others, as long as they can form an adequate cognitive representation of the other's mental state (Bernhardt and Singer, 2012; Blair, 2008). Another, non-exclusive, explanation is that the high autistic traits group learned the CS–US contingencies at least as well as the low autistic group. Previous studies on Pavlovian fear learning in ASD patients has shown both intact (Bernier et al., 2005; South et al., 2011) and attenuated (Gaigg and Bowler, 2007) fear learning in ASD patients.

Empathy consists of a number of subprocesses, such as emotional contagion and empathic appraisals (Preston and De Waal, 2002). A recent study (Olsson et al., submitted for publication), demonstrated that an increase in empathic appraisal of the observed models' thoughts and feelings during observational fear learning increased the strength of the subsequent expression of the CR. This was especially true in participants high in trait empathy, suggesting that observational fear learning is influenced by individual differences in empathic ability.

To better understand vicarious fear learning, more knowledge is needed about the allocation of attention to social and emotional cues, as well as variability in trait-like abilities to process social cognitive and emotional information. These processes are likely to be important for vicarious fear learning. Here, we draw on standard psychophysiology and eye-tracking methods to examine the physiological and attentional bases of vicarious fear learning. In addition, based on past research on relevant individual differences in learning from others' thoughts and feelings, we examined the impact of trait empathy and autistic traits on this kind of social learning.

1.3. The present study

The primary aim of the present study was to explore the processes underlying vicarious fear learning by examining eye movements. We therefore examined whether participants' spontaneous allocation of gaze during vicarious fear learning was related to (1) autonomic “social” unconditioned responses (UR) to a learning model, who expressed distress when receiving electric shocks, and (2) learning measured as differential SCR to the conditioned stimuli (CS) during the subsequent test phase in the absence of the learning model. We were also interested in whether participants' eye movements to the model and the displayed scene would differ depending on whether the displayed CS was predictive or not predictive of a shock to the learning model We expected that participants would look differently at the scene as a function of which