Computers in Human Behavior 91 (2019) 192–200

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

Full length article

Cue conditioning using a virtual spider discriminates between high and low spider fearful individuals

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ARTICLE INFO

Keywords:
Fear conditioning
Acquisition
Extinction
Spider-related fear
Virtual reality

ABSTRACT

The fear conditioning paradigm is one of the most commonly used procedures to examine the etiology and treatment of anxiety disorders in laboratories. However, findings with this procedure often do not generalize to clinical settings. Virtual reality (VR) is a promising tool for improving the ecological and predictive validity of fear conditioning. The current study explored whether a classical differential cue conditioning paradigm with spider-fearful participants can be conducted in a VR-environment. Specifically, 25 spider-fearful and 25 non-fearful female students participated in a fear-conditioning experiment with a virtual spider as an unconditioned stimulus (US). The experiment took place in a virtual office in which participants viewed an avatar of themselves sitting at a desk. Conditioned stimuli (CS) were a blue (CS+; 100% reinforcement) and a green (CS-) light emitted by a desk lamp. Fear reactions were measured by fear ratings, skin conductance responses (SCR), and fear potentiated startle responses (FPS). Our results indicated stronger differential fear conditioning for spider-fearful participants than for non-fearful participants. Furthermore, we demonstrate that these results relate specifically to spider-fear, and not to general trait anxiety. We conclude that fear conditioning in VR is a promising tool to improve the validity of classical fear conditioning procedures.

1. Introduction

The etiology of fear and anxiety related disorders is mostly studied in the laboratory using the Pavlovian fear conditioning procedure (Mineka & Zinbarg, 2006). In a Pavlovian cue conditioning paradigm, a neutral conditioned stimulus (CS+; e.g., color of a light) is paired with an aversive unconditioned stimulus (US; e.g., electrotactile stimulation), resulting in fearful responses to the CS. In humans, often a differential conditioning procedure is often used, in which a second conditioned stimulus (CS-) is shown without the US (Lipp, 2006). These conditioning paradigms have been useful in studying the acquisition, expression, generalization, and inhibition of threat-related behavior, as conditioning is believed to be one of the underlying mechanisms of anxiety and stress disorders (Mineka & Oehlberg, 2008; Mineka & Zinbarg, 2006).

Despite its success, fear-conditioning research has several methodological limitations. That is, fear conditioning research is traditionally performed in laboratory settings, where simple and static stimuli are used (Parsons, 2015). These fear conditioning tasks usually represent a "strong situation", whereby encountered stimuli by an individual are unambiguous (Lissek, Pine, & Grillon, 2006). In strong situations, individuals show a similar (adaptive) response pattern, limiting variability across individuals. "Weak situations" characterized by ambiguity and uncertainty might provide better opportunity to discover individual differences, such as differences in fear learning patterns between patient populations and healthy controls (Beckers, Krypotos, Boddez, Effting, & Kindt, 2013). Although strong situations contribute to the high internal validity of experimental research (Scheveneels, Boddez, Vervliet, & Hermans, 2016), it has been argued that research in laboratories lack potentially important aspects of real world circumstances, resulting in low ecological validity (Parsons, 2015). Therefore, laboratory findings possibly cannot be generalized to people's everyday life (Parsons, 2015), and clinical practice (Scheveneels et al., 2016). For example, individual differences which are known risk factors for developing anxiety disorders, such as trait anxiety and the BDNF-val66met polymorphism, do not appear to modulate fear conditioning (Torrents-Rodas et al., 2012, 2013). Such findings are problematic for the idea that fear conditioning procedures allow examination of processes involved in the etiology of anxiety disorders (Beckers et al., 2013). Investigating fear conditioning by including real world settings can improve ecological and predictive validity, but at the cost of lower internal validity and experimental control, and higher economical costs (Parsons, 2015; Shiban, Reichenberger, Neumann, & Mühlberger, 2015).

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https://doi.org/10.1016/j.chb.2018.10.006
Received 12 June 2018; Received in revised form 13 September 2018; Accepted 1 October 2018
Available online 02 October 2018
0747-5632/

A promising new technology to improve the ecological and predictive validity of experimental models is virtual reality (VR) (Baas, Nugent, Lissek, Pine, & Grillon, 2004; Cuperus, Laken, Van Den Hout, & Engelhard, 2016; Dibbets & Fonteyne, 2015; Huff, Zeilinski, Fecteau, Brady, & LaBar, 2010; Shiban et al., 2015). VR uses head-mounted displays to present digitally recreated real-world environments and activities. Advances in VR-technology have improved the quality and ease of stimulus presentation, data collection, and processing, at a decreasing cost (Parsons, 2015). Hence, VR provides a feasible solution to use more ecologically valid stimuli without requiring large investments of time or money. Furthermore, in VR simulations, environment- and confounding variables can be controlled, providing experimental control, dynamic stimuli presentation, and better standardization (Parsons, 2015; Shiban et al., 2015). VR simulations can also give a sense of immersion (i.e., a strong feeling of being present in the virtual environment). People tend to think, behave, and feel as if they are in the virtual space, rather than in the real world (Kroes, Dunsmoor, Mackey, McClay, & Phelps, 2017). In fact, this feeling of 'presence' might influence fear perception (Juan & Pérez, 2009; Ling, Nefs, Morina, Heynderickx, & Brinkman, 2014), and can be enhanced by the presence of virtual hands (Peperkorn, Diemer, Alpers, & Mühlberger, 2016). Finally, VR-technology offers a set of tools to track motion- and eye-movement, facilitating the measurement of spontaneous behavior.

Despite its promising features to improve ecological and predictive validity, VR technology has not yet been extensively been used in fear conditioning research. Previous studies using virtually reality have shown that VR can be used to model acquisition, extinction, spontaneous recovery, and generalization of fear in cue conditioning (Baas et al., 2004; Ewald et al., 2014), social conditioning (Shiban et al., 2015), and context conditioning (Glotzbach, Ewald, Andreatta, Pauli, & Mühlberger, 2012; Huff et al., 2011). However, older VR-studies have typically used 3D-simulations presented on monitors, instead of a head-mounted display (HMD) which later became commercially available with the development of systems such as the Oculus Rift or the HTC Vive. The use of HMDs provide much higher levels of immersion and presence in the situation, which may be relevant for participants' fear levels (Bowman & McMahan, 2007; Juan & Pérez, 2009; Ling et al., 2014). Furthermore, most fear conditioning studies use pain signals (e.g., electro-tactile stimulation) as US, whereas a more naturalistic US could improve external validity of the conditioning procedure. In particular, disorder-relevant USs have been shown to facilitate fear conditioning, emphasizing the importance of disorder-relevant USs (Lissek et al., 2008). Lastly, differences in conditioning have been found for both individual characteristics and clinical samples (Lissek et al., 2008). Therefore, studies using sub-clinical participants might help in uncovering some of the underlying etiological and pathology-maintaining mechanisms in their associated clinical group. So far, only a few studies investigating fear conditioning in VR-environments used sub-clinical samples (Mosig et al., 2014) or participants at risk of developing anxiety disorders (Glotzbach-Schoon, Andreatta, et al., 2013; Glotzbach-Schoon, Tadda, et al., 2013; Shiban et al., 2015), which limits our understanding of the feasibility of using this technology with these groups.

In the current study, we wanted to investigate whether VR can be used to investigate conditioning processes in specific phobia. Specific phobia is one of the most common mental health disorders in Europe (Alonso et al., 2004; Bandelow & Michaelis, 2015). Worldwide, specific phobia has a lifetime prevalence of 7.4% in the general population, with higher rates found in females (9.8%) than in males (4.9%) (Wardenaar et al., 2017). Of specific phobias, fear of animals is one of the most common DSM-subtypes, of which spider phobia is among the most prevalent, and most studied (Miloff et al., 2016). In fact, it is particularly interesting to study fear conditioning and extinction processes in specific phobias because especially for specific phobias, conditioning experiences are believed to be causally related onset and maintenance of the disorder (Field, 2006; Schindler, Vriends, Margraf, & Stieglitz, 2016). However, studies with patients often fail to find evidence for the involvement of conditioning processes in specific phobia (Menzies & Clarke, 1995; Rachman, 1977). This may be due to memory biases and forgetting in studies with patients, who often already suffer from their condition for many years. Therefore, studies with participants reporting sub-clinical levels of fear can be particularly informative to determine whether conditioning processes are different prior to the onset of a specific phobia. Finally, for spider phobia exposure therapy in a VR-environment is already available and effective (Garcia-Palacios, Hoffman, Carlin, Furness, & Botella, 2002; Michaliszyn, Marchand, Bouchard, Martel, & Poirier-Bisson, 2010; Opriş et al., 2012; Shiban, Pauli, & Mühlberger, 2013). This suggests that spider-related fear can be safely studied in a VR-simulation.

Given these features of specific phobia, and particularly spider phobia, the aim of the current study was to explore whether VR technology could be used to create a more ecologically valid version of the fear conditioning procedure for participants with sub-clinical levels of fear for spiders. Therefore, a virtual office environment was used whereby participants viewed an avatar of themselves sitting at a desk. A female avatar was chosen, because spider phobia is more common among women (Fredrikson, Annas, Fischer, & Wik, 1996). We used a VR spider as an ecologically valid and disorder-relevant US, which was paired with a neutral CS (i.e., a blue light emitted by a desk lamp; CS +). Following the typical differential fear conditioning procedure with humans, a second CS (i.e., a green light; CS-) was not paired with the virtual spider. As a control condition, we included a group of participants without fear for spiders. Aversive responses were measured by subjective fear ratings, skin conductance response, and the startle response. We hypothesized that a more ecologically valid US could be used to condition participants in a VR environment, specifically for participants for who this US is likely unpleasant and aversive.

2. Method

2.1. Pilot study

An explorative pilot study was conducted to determine optimal spider presentation parameters for provoking fearful responses in spider fearful participants, following a similar procedure and the same setting (i.e., a virtual office) as the main study. In total, six participants took part in the pilot (2 men; 4 women), with an average score of 61.33 (SD = 27.78) on the Fear of Spider Questionnaire (FSQ). Two female participants dropped out beforehand, due to too little and too much fear of spiders (FSQ scores of 38 and 110, respectively). The pilot consisted of 10 spider presentations (duration: 15 s, inter-trial interval: 10 s) that were presented in clusters of three, after which participants were asked to select the most fear-inducing spider ("Which spider did you find most annoying to see?", available options: first, second or third spider). In each cluster, different spider characteristics were varied (e.g. size, movement speed, or both). The last trial contained a small technical glitch in the spider's movement, to assess whether this influenced the participant's experience. Using a short structured interview at the end of the pilot, we found that spiders intermediate in size and that varied in trajectory and movement speed were perceived as the most unpleasant in this sample.

2.2. Pre-registration main study

The sample size determination, design, procedure, and data analyses steps of the main study were pre-registered on the Open Science