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Trait anxiety and post-learning stress do not affect perceptual learning

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ABSTRACT

While it is well established that stress can modulate declarative learning, very few studies have investigated the influence of stress on *non-declarative learning*. Here, we studied the influence of post-learning stress, which effectively modulates declarative learning, on perceptual learning of a visual texture discrimination task (TDT). On day one, participants trained for one session with TDT and were instructed that they, at any time, could be exposed to either a high stressor (ice–water; Cold Pressor Test; CPT) or a low stressor (warm water). Participants did not know when or which stressor they would be exposed to. To determine the impact of the stressor on TDT learning, all participants returned the following day to perform another TDT session. Only participants exposed to the high stressor had significantly elevated cortisol levels. However, there was no difference in TDT improvements from day one to day two between the groups. Recent studies suggested that trait anxiety modulates visual perception under anticipation of stressful events. Here, trait anxiety did neither modulate performance nor influence responsiveness to stress. These results do not support a modulatory role for stress on non-declarative perceptual learning.
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1. Introduction

Stress and the corresponding release of glucocorticoids modulate declarative human memory (reviews: Het, Ramlow, & Wolf, 2005; Joels, Pu, Wiegert, Oitzl, & Krugers, 2006; Sandi & Pinelo-Nava, 2007; Shors, 2006). For example, exposure to ice-water (CPT; Cold Pressor Test) directly after presentation of pictures improved memory of the pictures when tested 1 week later (Cahill, Gorski, & Le, 2003). Pharmacologically induced elevations of cortisol levels deteriorated word learning (Kirschbaum, Wolf, May, Wippich, & Hellhammer, 1996). The influence of stress on learning and memory is heterogeneous and varies depending on the emotional content and the valence of stimuli (Buchanan & Lovallo, 2001; Cahill & Alkire, 2003; Cahill et al., 2003; Rimmele, Domes, Mathiak, & Hautzinger, 2003; Schwabe, Bohringer, Chatterjee, & Schachinger, 2008; Southwick et al., 2002), timing of stress (before the learning: Lupien et al., 2002; Maheu, Collicut, Kornik, Moszkowski, & Lupien, 2005; Schwabe et al., 2008; after the learning: Andreano & Cahill, 2006; Cahill et al., 2003), the intensity of stress (Andreano & Cahill, 2006; Maheu, Collicut, et al., 2005; Kirschbaum et al., 1996) and memory type (Kirschbaum et al., 1996; Luethi, Meier, & Sandi, 2009). Most studies addressing the influence of stress on memory used paradigms tapping into declarative memory.

In contrast, only a few studies investigated how stress modulates non-declarative memory formation (Kirschbaum et al., 1996; Luethi et al., 2009; Lupien et al., 1997). In one of these studies, participants were first exposed to a stressor and then performed a battery of memory tasks including classical conditioning with emotionally positive and negative stimuli, as well as perceptual and conceptual priming tasks (Luethi et al., 2009). Stress had no influence on the priming tasks and the only significant effect in the conditioning task was found with negative stimuli. These results indicate that stress may influence non-declarative learning to some extent, however, it is not clear which phase of learning was affected because memory recall was tested shortly after performing the tasks. Hence, little time was allowed for memory consolidation and for the stress response to decline prior to memory recall. For declarative learning, different phases of learning are influenced differently by stress (Het et al., 2005; Roozendaal, 2002). It is therefore important to systematically study the influence of stress on different phases of learning also for non-declarative learning. Furthermore, previously tested non-declarative learning tasks are rather short-term and may not depend on the post-learning phase, i.e. consolidation, which has been shown to be sensitive to the influence of stress and changes in cortisol levels (Roozendaal, 2002; Sandi, 1998; Shors, 2006). Here, we used a visual perceptual learning paradigm, known to be sensitive to post-learning manipulations (consolidation), to study how

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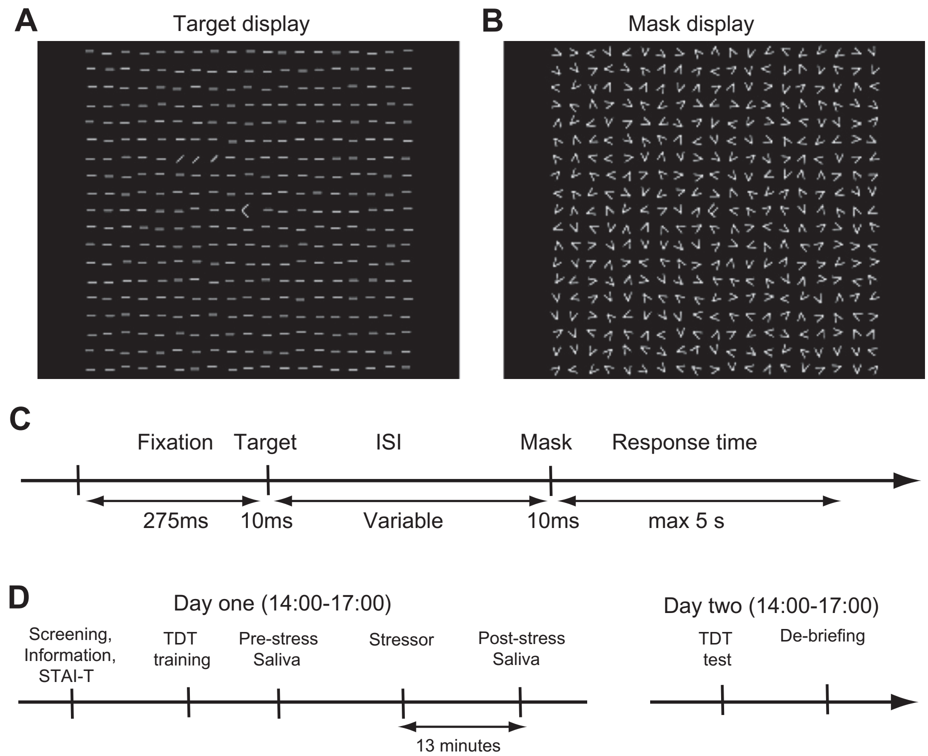

Fig. 1. TDT experiment: stimuli and procedure. (A) Three diagonal target bars were presented within a background of horizontal bars. The target texture could be either horizontal or vertical (here, a horizontal target array is shown). A rotated letter in the center served as a fixation task. This letter could be either a rotated L or a rotated T (here, a rotated L is shown). (B) The mask display consisted of randomly oriented V-shapes. In the center, a compound pattern of superimposed T's and L's was presented. (C) In each trial, a blank screen with a red fixation dot was presented for 275 ms followed by a target display presented for 10 ms. The target was followed by a blank screen for a variable amount of time (ISI) which was followed by a mask presented for 10 ms. Following the mask, a blank screen was presented for 5 s or until participants responded. (D) Experimental procedure. On the afternoon of day one, participants arrived in the lab and were tested for visual acuity, informed about the procedure, provided written consent and filled out the STAI-T questionnaire. Directly after, participants trained with the visual texture discrimination task. A saliva sample was collected immediately following training. Then, participants were exposed to a stressor which was followed 13 min later by the collection of another saliva sample. Participants returned in the afternoon the following day to perform a second session with the texture discrimination task and were de-briefed directly after.

stress influences consolidation of non-declarative perceptual learning.[1]

Perceptual learning is the ability to learn to perceive (review: Fahle & Poggio, 2002). Visual perceptual learning is a non-declarative form of learning that improves discrimination of basic visual stimulus features including vernier acuity (Crist, Kapadia, Westheimer, & Gilbert, 1997; Herzog & Fahle, 1997), contrast (Kuai, Zhang, Klein, Levi, & Yu, 2005; Yu, Klein, & Levi, 2004), motion (Ball & Sekuler, 1982; Liu & Vaina, 1998) and textures (Censor, Karni, & Sagi, 2006; Karni & Sagi, 1993; Mednick, Arman, & Boynton, 2005; Stickgold, LaTanya, & Hobson, 2000). In a texture discrimination task (TDT), participants determine the orientation of an array of target elements within distracter elements (Fig. 1A). Task difficulty is controlled by the ISI (Inter-Stimulus Interval) between the target display and a mask display (Fig. 1A). The ISI limits the temporal availability of a stimulus and reflects the time needed to obtain a workable percept. Thus, the ISI is a measure of perceptual performance and becomes potent with experience (Karni & Sagi, 1991, 1993; Karni, Tanne, Rubenstein, Askenasy, & Sagi, 1994). A short ISI indicates good performance. Importantly, consolidation and sleep are often needed to improve texture discrimination (Censor et al., 2006; Karni et al., 1994; Mednick, Nakayama, & Stickgold, 2003; Stickgold, Whidbee, Schirmer, Patel, & Hobson, 2000; Yotsumoto, Chang, Watanabe, & Sasaki, 2009). For example, performance between two sessions did not improve unless they were separated by a night (Karni & Sagi, 1993; Karni et al., 1994; Stickgold, LaTanya, et al., 2000; Stickgold, Whidbee, et al., 2000; Yotsumoto, Chang, et al., 2009). Furthermore, training another task directly after the TDT abolished performance improvements (Yotsumoto, Chang, et al., 2009) suggesting that this task is sensitive to post-learning manipulations (see also Beer, Vartak, & Greenlee, 2012). Finally, sleep deprivation increased cortisol levels (Meerlo, Sgoifo, & Suchecki, 2008) and disrupted consolidation of the TDT (Stickgold, LaTanya, et al., 2000). Accordingly, these results suggest that (1) TDT can be disrupted by post-learning manipulations and (2) these manipulations may involve stress and increased cortisol levels.

To test if stress modulates TDT learning, two groups of participants trained two sessions with the TDT on two consecutive days (Fig. 1C). After TDT training on day one, participants in the stress group immersed their arms into ice water (0–4 °C; Lovallo, 1975) while participants in a control group immersed their arms into warm water (37–40 °C). To determine whether this stress manipulation induced changes in cortisol levels, saliva was collected before and after stressor exposure. Participants returned the following day for another TDT session.

Besides studying the influence of stress on perceptual learning, we were also interested in studying the influence of trait anxiety on visual perception and learning. Laretzaki, Plainis, Argyropoulos,

[1] Following declarative learning participants have conscious recollection of the learning experience and the information learned. Declarative memory can be accessed by explicit measures, for example by asking: What did you have for breakfast this morning? Non-declarative memories cannot be verbalized and need to be accessed by implicit measures. For example, learning to ride a bike can be accomplished, even though it is impossible to verbalize how it was learned. Similarly, perceptual learning is an implicit measure used to tap into non-declarative memories.

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