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Perceptual-motor learning benefits from increased stress and anxiety

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ABSTRACT

The purpose of this study was to manipulate psychological stress and anxiety to investigate effects on ensuing perceptual-motor learning. Thirty-six participants attended two experimental sessions separated by 24 h. In the first session, participants were randomized to either a mental arithmetic task known to increase stress and anxiety levels or a control condition and subsequently completed training on a speeded precision pinch task. Learning of the pinch task was assessed at the second session. Those exposed to the high stress-anxiety mental arithmetic task prior to training reported elevated levels of both stress and anxiety and demonstrated shorter movement times and improved retention of movement accuracy and movement variability. Response execution processes appear to benefit from elevated states of stress and anxiety immediately prior to training even when elicited by an unrelated task.

1. Introduction

The effects of stress and anxiety on performance and learning have significant implications for human functioning. To describe the influence of stress and anxiety on performance, theoretical frameworks have emphasized adaptation and appraisal as moderating factors. According to the maximal adaptability model (Hancock & Warm, 1989), adaptive responses allow for the maintenance of performance under stress, however negative consequences and the experience of anxiety may be observed beyond the threshold for adaptation (Blascovich, 2008; Blascovich & Tomaka, 1996). The process of adaptation and appraisal to a stressor, task or challenge likely involves changes in resource availability or allocation. These processes frequently incorporate physiological, cognitive, behavioral and emotional dimensions to regulate response to the stressor or task (Staal, 2004). For example, stress is associated with activation or arousal that allow for optimal information processing (Cannon, 1915; Duffy, 1957; Gaillard, 2001; Hockey, 1997). Where appraisal of task demands can be matched by resource availability, positive consequences would be expected. The converse would be true when appraisal of task demands exceeds resource availability.

Unfortunately, theoretical frameworks that aim to explain the effects of stress and anxiety on performance largely ignore the role of learning. While it is necessary to infer learning from performance, the two are not equivalent. Performance does not necessarily reflect learning as it is readily influenced by transient conditions, termed performance variables. Learning on

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the other hand represents relatively permanent changes in the capacity for behavior, in this case consistent improvements in performance. This distinction is important because findings suggest that stress and anxiety are detrimental to motor performance during early stages of learning but have no effect, or improve performance during later learning stages (Hardy, Mullen, & Jones, 1996; Masters, 1992; Vine, Freeman, Moore, Chandra-Ramanan, & Wilson, 2013). Previous studies are equivocal with respect to the effects of stress and anxiety on perceptual-motor learning as some have reported benefits (Duncko, Cornwell, Cui, Merikangas, & Grillon, 2007; Marteniuk & Wenger, 1970; Oudejans & Pijpers, 2009; Oudejans & Pijpers, 2010; Sage & Bennett, 1973), others impaired motor learning (Cox, 1983; Noteboom, Barnholt, & Enoka, 2001), while still others have reported no effect (Calvo, Alamo, & Ramos, 1990; Carron & Morford, 1968; Pemberton & Cox, 1981). Further clarification of the effects of stress and anxiety on motor learning is required.

Traditionally, stress is defined as a physiological response to the perceived task or situational demands, relative to the available resources to cope with the demands (Stokes & Kite, 2001). Anxiety is defined as negative expectations and concerns about oneself, the situation at hand, and the potential consequences (Morris, Davis, & Hutchings, 1981). Although stress is commonly connected to anxiety (Tepas & Price, 2001), they may engage different emotions representing adaptive or aversive responses to learning and performance respectively (Watson & Clark, 1997; Watson & Tellegen, 1985). In terms of motor performance and learning, stress might be adaptive since stress reflects a states of increased readiness (Coombes, Gamble, Cauraugh, & Janelle, 2008; Lang, Bradley, & Cuthbert, 1998) and preparedness for action (Schupp, Junghofer, Weike, & Hamm, 2003). For example, higher levels of stress has been shown to subsequently improve performance on a manual dexterity task (Wegner, Koedijker, & Budde, 2014). Anxiety, on the other hand, may be aversive due to the threat (Blascovich, 2008; Blascovich & Tomaka, 1996) that results from exceeding the capacity of information processing or motor performance. It is the aversive nature of anxiety that results in learning and performance decrements (Frings, Rycroft, Allen, & Fenn, 2014; Hancock & Warm, 1989; Moore, Vine, Wilson, & Freeman, 2012; Vine et al., 2013). For example, increased state anxiety has been associated with poorer sport competition performance (Demoja & Demoja, 1986). Thus, stress and anxiety might have divergent effects on motor learning, representing a continuum by which negative emotion provides an adaptive benefit up to an optimal point beyond which further increases are aversive and consequently disruptive (Marteniuk, 1976; Weinberg & Ragan, 1978).

However, there is an opposing view to the notion that anxiety is detrimental to performance. Instead, anxiety might benefit learning and performance through increased allocation of processing resources to avoid performance loss and counteract worry associated with potential performance loss (Eysenck, Derakshan, Santos, & Calvo, 2007). This would be consistent with research reporting motor learning benefits from anxiety (Oudejans & Pijpers, 2009; Oudejans & Pijpers, 2010; Sage & Bennett, 1973), although these benefits might depend on reintroduction of anxiety (Lawrence et al., 2014; Oudejans & Pijpers, 2010). Thus, even if stress and anxiety represent different negative emotions, their effects on motor learning and performance might be comparable.

An additional complication is that the influence of stress and anxiety on motor learning might depend on how they arise within the learning environment. Previously, stress and anxiety have been manipulated either directly or indirectly with a variety of conditions such as task instructions (Calvo et al., 1990), introduction of a secondary task (Hardy et al., 1996), introduction of competitive pressure (Oudejans & Pijpers, 2009), or differing height levels on a rock climbing wall (Oudejans & Pijpers, 2010). Some of these conditions might confound the effects of stress with other sources of interference including those arising from the task itself (e.g. secondary tasks require attentional demand). Thus, there is a need to better investigate the effect of stress on motor learning by distinguishing stress influences from task influences. Typically, the motor task itself is a proximal source of stress (Hancock & Warm, 1989) making it difficult to determine if the consequences on performance effects arise from stress or the characteristics of the task. Rendering the task as the source of stress and anxiety is not necessary since stress and anxiety are nonspecific responses (Selye, 1973) with after-effects evident following removal of the stressor (Joëls, Pu, Wiegert, Oitzl, & Krugers, 2006). Accordingly, the effects of stress and anxiety on motor learning might be better investigated by manipulation prior to and independent from the motor task.

The purpose of this study was to investigate the effects of induced acute psychological stress and anxiety on subsequent perceptual-motor learning. We hypothesised that acute psychological stress and anxiety would influence both movement preparation and execution, resulting in a speed-accuracy trade off (Leon & Revelle, 1985) during a speeded submaximal pinch grip task. Importantly, we used a methodological approach that induced high levels of stress and anxiety prior to the task itself in order to more directly test their effect on motor learning. Divergent effects on motor learning would be predicted if stress is adaptive (i.e., increases performance capacity) while anxiety is aversive or disruptive (i.e., decreases performance capacity). In contrast, if stress and anxiety are both adaptive then these negative emotions would provide comparable benefits for motor learning and performance.

2. Method

2.1. Participants

Thirty-six apparently healthy adult volunteers (20 female, 16 male), aged 18–34 (M = 23.3, SD = 3.4) years participated in the present study. Of these participants, 31 (86.1%) were right-hand dominant and 5 (13.9%) were left-hand dominant as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971). Ethics approval was provided by the University of