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Effects of trait test anxiety and state anxiety on children's working memory task performance

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ABSTRACT

This study examined the effects of (a) trait test anxiety versus state anxiety and (b) working memory load on children's mental arithmetic task performance. Participants ($N = 128$; 11-year-olds) completed a mental arithmetic task at varying levels of working memory load under high and low situational stress conditions. Measures of task accuracy and accuracy/response time served as indicators of performance effectiveness and processing efficiency. The findings showed that trait test anxiety has a direct and detrimental effect on working memory. The effect was not mediated by state test anxiety. We also demonstrated that the adverse effects of trait test anxiety on efficiency are independent of working memory load. However, anxiety-related deficits in effectiveness occur at higher levels of working memory load. Findings are interpreted as being largely consistent with the attentional control theory.

1. Introduction

The negative relation between anxiety and task performance is well-documented in children and adults (e.g., Eysenck, Derakshan, Santos, & Calvo, 2007; Owens, Stevenson, Hadwin, & Norgate, 2012, 2014). Within the school context, test anxiety correlates negatively with performance on aptitude and achievement measures (Hembree, 1988; Ma, 1999). These findings indicate that test anxiety can potentially jeopardize the validity of examination results because test-anxious individuals do not perform as well as their ability would otherwise allow (Zeidner, 1990).

Our present investigation of the effects of test anxiety on cognitive performance is guided by two theoretical frameworks: the attentional control theory (ACT; Eysenck et al., 2007) and the processing efficiency theory (PET; Eysenck & Calvo, 1992). Although both theories are focused on general trait and state anxiety, they have been applied to test anxiety (Eysenck et al., 2007, p. 336; see also Mowbray, 2012). Both theories make a distinction between performance effectiveness and processing efficiency. Effectiveness refers to the quality of task performance and is primarily measured by response accuracy. Efficiency is defined as effectiveness divided by effort and can be measured by accuracy divided by response time (Hoffman, 2012).

1.1. Roles of trait test anxiety and state anxiety on task performance

Despite the extensive literature on test anxiety and cognitive performance, an issue that remains unresolved is the relative contributions of trait test anxiety versus state anxiety to cognitive performance. According to Spielberger (1972), trait test anxiety refers to an individual's disposition to perceive test situations as threatening and to respond to such threats with state anxiety (i.e., transient feelings of negative arousal). Both the ACT and the PET assume that anxiety-related deficits primarily affect efficiency, but not effectiveness. The PET assumes that it is the level of state (rather than trait) anxiety that determines individual differences in performance (Eysenck & Calvo, 1992, p. 414). In contrast, the ACT puts a stronger emphasis on the effects of individual differences in trait anxiety (Eysenck & Derakshan, 2011, p. 955).

Few studies have attempted to disentangle the effects of trait versus state anxiety on task performance. In most studies, trait anxiety comparisons were examined in either a high or a low situational stress condition, but not both (e.g., Eysenck, Payne, & Derakshan, 2005; Hayes, MacLeod, & Hammond, 2009; Visu-Petra, Miclea, Cheie, & Benga, 2009). On the whole, these studies have found that high trait-anxious individuals showed poorer task performance compared to their low trait-anxious counterparts. A crucial limitation of previous studies is the absence of a state or situational stress manipulation that examined how it interacted with trait anxiety. Assessments of state anxiety were noticeably absent in some studies (Johnson & Gronlund, 2009; Visu-Petra, Cheie, Benga, & Alloway, 2011), partly due to the assumption that high trait anxiety is synonymous with high state anxiety

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(Eysenck & Calvo, 1992). Because of these limitations, it is difficult to establish whether observed performance impairments are due to trait anxiety or elevated state anxiety levels. Indeed, studies that used state anxiety scores as the basis for anxiety group assignment also observed anxiety-related decrements in task performance (Derakshan, Smyth, & Eysenck, 2009; Hadwin, Brogan, & Stevenson, 2005).

In recent years, more researchers have begun investigating the effects of both trait and state anxiety. Moriya and Tanno (2009) found no significant correlations between trait or state anxiety with executive control, as measured by the attention network test. Contrary to these findings, Pacheco-Unguetti, Acosta, Callejas, and Lupianez (2010) found an adverse effect of high trait anxiety on executive control, after controlling for differences in state anxiety. More recently, Quigley, Nelson, Carriere, Smilek, and Purdon (2012) investigated low, mid and high trait-anxious participants' performance on an eye-tracking task. Using a mood induction procedure, each participant completed the task under low- and high-anxious conditions. Quigley et al. (2012) found that an increase in state anxiety levels was associated with increased attention to threat, regardless of trait anxiety levels.

To summarize, our current understanding of the relative contributions of trait and state anxiety on cognitive performance is limited. Furthermore, studies involving school-aged children are relatively scarce (Visu-Petra, Cheie, & Mocan, 2013). A notable exception is Ursache and Raver's (2014) study on 9- to 12-year-olds' performance on executive functioning tasks. Their study demonstrated that higher levels of trait (not state) anxiety were associated with poorer performance on shifting and inhibition tasks. The present study aims to bridge this gap by examining whether trait test anxiety has a direct or indirect effect, via state anxiety, on cognitive performance in 11-year-olds.

1.2. Role of working memory load

In addition to trait versus state anxiety, we also examined the role of working memory (WM) load. According to the PET, anxiety-related worry cognitions consume WM capacity (Baddeley, 1986, 2001), leaving a smaller functional capacity for the task at hand. The ACT assumes that anxiety increases the allocation of attentional resources to worry, thus reducing attentional focus on the current task (Eysenck et al., 2007). The ACT specifies that worry also motivates anxious individuals to compensate for the restricted availability of WM by increasing their effort and using auxiliary resources. As a consequence, anxiety typically impairs efficiency to a greater extent than it does effectiveness. However, the use of compensatory strategies becomes more difficult when the task's WM load increases. In such a scenario, there will likely be commensurate decrements in effectiveness (Eysenck et al., 2007).

The interplay between anxiety and WM has been observed in a large number of studies (e.g., Eysenck & Derakshan, 2011; Visu-Petra et al., 2013). Based on these findings and the ACT framework, the effects of anxiety on WM constitute a plausible mechanism for the well-documented link between anxiety and performance. In support of this hypothesis, Owens and his colleagues have demonstrated a mediating role for WM in the relation between trait anxiety and academic performance in 11- to 13-year-olds. These studies showed, from a *differential* perspective, that individual differences in verbal WM (Owens, Stevenson, Norgate, & Hadwin, 2008) and central executive functioning (Owens et al., 2012) mediated the negative relation between trait anxiety and academic performance. The role of WM has also been examined from an *experimental* perspective by manipulating the availability of WM resources for task performance. In some studies, the adverse effects of anxiety on task performance were limited to tasks with higher WM load (Cheie, Visu-Petra, & Miclea, 2012; Derakshan et al., 2009). However, others have reported adverse effects of anxiety on efficiency at high and low levels of WM load (Hadwin et al., 2005; Visu-Petra et al., 2011). In another study involving 11-year-olds, Ng and Lee (2010) compared high and low trait-test-anxious children's performance on a mental arithmetic task at low and high WM load. They found no interaction effect between test anxiety and WM load on children's mental arithmetic performance.

MacLeod and Donnellan (1993) argued that the role of WM load was not properly addressed in some studies as the tasks' extraneous characteristics were inadequately controlled. This criticism also applies to more recent studies. For example, Visu-Petra et al. (2011) examined the effects of trait anxiety on low-load storage-only tasks (e.g., word span) and high-load storage-and-processing tasks (e.g., counting recall). On the storage-only tasks, highly trait-anxious children showed only efficiency deficits, but on the storage-and-processing tasks, both efficiency and effectiveness were impaired. Although these results suggest a stronger effect of anxiety on tasks with higher WM load, the authors cautioned that the two types of tasks cannot be directly contrasted as the tasks' storage demands were not identical. To overcome this interpretative ambiguity, we examined the role of WM load using a memory recall task, in which WM load was systematically varied. This task was one of two tasks that were performed simultaneously (MacLeod & Donnellan, 1993).

1.3. The present study

The aim of this study was to investigate the effects of (a) trait test anxiety versus state anxiety and (b) WM load on children's mental arithmetic task performance. Regarding the roles of trait test anxiety and state anxiety, we tested two hypotheses. Hypothesis 1a is derived from a PET assumption that the relation between trait and state anxiety is moderated by situational stress (Eysenck & Calvo, 1992, p. 414). We tested a moderated mediation hypothesis in which state anxiety mediated relations between trait test anxiety and task performance in situations of high, but not low, situational stress. This mediational effect of state anxiety was expected to be significant only at high situational stress (see paths labeled "H1a" in Fig. 1). Hypothesis 1b was derived from the ACT, which puts a stronger emphasis on the effects of individual differences in trait anxiety on cognitive performance (Eysenck & Derakshan, 2011, p. 955). We interpreted this to suggest that trait test anxiety would directly influence task performance regardless of state test anxiety levels (see path labeled "H1b" in Fig. 1).

The ACT specifies that anxiety has a disruptive effect on WM capacity and previous studies have demonstrated a mediating effect of WM in the relation between trait anxiety and academic performance (e.g., Owens et al., 2012). We propose that test anxiety impacts WM in a similar fashion: an increase in load on the memory recall task would negatively impact highly test-anxious children's performance on the mental arithmetic task. It was expected to do so because highly anxious children would already have expended some of their WM resources on worrying thoughts. One complication comes from recent findings showing that high-anxious individuals with high WM capacity were buffered against the disruptive effects of both anxiety (Johnson & Gronlund, 2009) and maladaptive motivational goals (Lee, Ning, & Goh, 2014). Thus, we expected that amongst highly test-anxious children, those with higher WM capacity would be less affected by a higher WM load than those with lower WM capacity. We did not measure directly individual differences in WM capacity. Instead, we expected performance on the memory recall task to be affected primarily by individual differences in WM capacity. For this reason, we proposed Hypothesis 2, which states that performance on the memory recall task mediated the link between trait test anxiety and mental arithmetic performance, particularly at higher levels of WM load (see paths labeled "H2" in Fig. 1).

2. Method

2.1. Participants and design

Participants were 128 11-year-olds (M_{age} = 10.68 years, SD = 0.58, 55 boys) enrolled in seven public primary schools serving families with