Title: 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.

Keywords: Attentional control theory, processing efficiency theory, dual-task performance, academic achievement.
Effects of Trait Test Anxiety and State Anxiety on Children's Working Memory Task Performance

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 (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, Carrier, 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
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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 Figure 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 Figure 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

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Figure 1. Path diagram of hypothesized models for accuracy and efficiency. WM = working memory. Situational stress was a bivariate
dummy variable that corresponded to the low versus high situational stress condition. Experimental order was also a bivariate dummy
variable. The two interaction terms (trait test anxiety x situational stress and trait test anxiety x WM load) are represented by two lines
joining the corresponding main effects and a dot. The dashed line was added to the model to test for reciprocal relations between
memory recall and mental arithmetic performance.
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 Figure 1).

2. Method

2.1. Participants and design

Participants were 128 11-year-olds ($M_{\text{age}} = 10.68$ years, $SD = 0.58$, 55 boys) enrolled in seven public primary schools serving families with low- to middle-socioeconomic-status backgrounds in Singapore. Parental consent was obtained for all the participants, as well as informed written assent from each participant. The study was based on a 2 (situational stress: low versus high) x 3 (WM load: low versus medium versus high) within-subjects design. Trait test anxiety served as a continuous predictor. Accuracy and RT on the memory recall and mental arithmetic tasks served as dependent measures.

2.2. Materials

2.2.1. Trait test anxiety

The Test Anxiety Inventory (TAI; Spielberger et al., 1980) consisted of 20 statements describing various reactions towards tests and examinations (e.g., “I feel confident and relaxed while taking tests”). Participants rated how they generally felt about each statement on a scale of 1 (almost never) to 4 (almost always). TAI scores range from 20 to 80; higher scores reflect higher levels of trait test anxiety. In the current sample, internal consistency of the TAI was high with a Cronbach’s alpha of .89.

2.2.2. State anxiety

The State version of the State-Trait Anxiety Inventory for Children (STAIC; Spielberger, 1973) consisted of 20 statements describing various emotional states (e.g., calm, upset, nervous). Each statement began with the phrase “I feel …” followed by three choices (e.g., very calm, calm, not calm). Participants selected the option that best described how they felt at the present moment. The STAIC was administered immediately before (pre-test) and after (post-test) the experimental task. Test items were presented in a
different order at each assessment. STAIC scores range from 20 to 60; higher scores reflect higher levels of state anxiety.

2.2.3. Experimental task

Two parallel versions of the experimental task were created—one version was administered in the high situational stress condition and the other in the low situational stress condition. The task consisted of 96 trials presented in four blocks of 24 trials each. Data from the fourth block of trials were not used in our analyses (see explanation in Section 2.2.4). Each block contained an equal number of low, medium and high WM load trials presented in randomized order. In each trial, participants were first presented with a 6-letter memory load set (see Figure 2), which consisted of six As in the low WM load condition, a contiguous alphabet sequence in the medium load condition (e.g., “ABCDEF”) and similar sequences presented in randomized order in the high load condition (e.g., “DAECBF”). Participants were instructed to repeat the memory load set aloud while solving a mental arithmetic problem. They were instructed to provide their answers for the units first, followed by the tens by clicking on boxes numbered 1 to 9 on the computer screen using a mouse (e.g., the correct responses for 53 – 37 are “6” and “1”). This eliminates the need to maintain intermediate results in memory, thus removing a potential source of interference during the maintenance of the memory load set. After solving the arithmetic problem, participants recalled the memory load set by typing their responses on the keyboard. All stimuli were presented on a computer using E-Prime 2.0 (Schneider, Eschman, & Zuccolotto, 2002).

2.2.4. Manipulation of situational stress

In the high situational stress condition, participants were informed that the task was a test and that they would receive performance feedback after each trial. False (instead of performance-based) feedback was provided in order to simulate a situation in which children experienced repeated failure despite their best efforts (Dickerson & Kemeny, 2004). Upon completion of each trial, feedback was presented on the computer screen as a bar graph. Green and red bars represented success and failure feedback, respectively.
Children were told that success was contingent upon providing the correct answer as quickly as possible whereas incorrect answers or the inability to provide the correct answer sufficiently quickly was associated with failure. We associated a purported speed criterion (i.e., children’s speed of response was compared against other children) to performance to increase the likelihood that participants would perceive the feedback as credible.

<table>
<thead>
<tr>
<th>Low Memory Load Condition</th>
<th>Medium Memory Load Condition</th>
<th>High Memory Load Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 sec READY?</td>
<td>READY?</td>
<td>READY?</td>
</tr>
<tr>
<td>6.0 sec Memory Load Set</td>
<td>A A A A A A</td>
<td>A B C D E F</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D A E C B F</td>
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<tr>
<td>Recording of Mental Arithmetic Task Accuracy and RT</td>
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<td></td>
<td>Mental Arithmetic</td>
<td>Mental Arithmetic</td>
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<td>53</td>
<td>65</td>
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<td></td>
<td>37</td>
<td>29</td>
</tr>
<tr>
<td>Recording of Memory Recall Task Accuracy and RT</td>
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<td></td>
<td>Memory Recall Test</td>
<td>Memory Recall Test</td>
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</tbody>
</table>

*Figure 2.* Sequence of events for the experimental task. RT = response time. Mental arithmetic RT was derived as the time taken to perform two mouse clicks. Memory recall RT was derived as the time taken to perform six key presses.

The first three blocks of trials were engineered to provide negative feedback on 75% of the trials and positive feedback on the remaining trials. In other words, within each block of 24 trials, there were 18 negative feedback trials and 6 positive feedback trials. In the fourth block of trials, the ratio was reversed so that participants received more positive than negative feedback. This was aimed at reducing any negative effect of the false negative feedback on children’s emotional state. Across all four blocks of trials, feedback
was presented in a predetermined order to ensure that feedback was not consistently negative. This arrangement also reduces the predictability of the feedback, thus adding to the credibility of the manipulation.

In the low situational stress condition, participants were informed that the task was not a test. Importantly, performance feedback was not provided at all in this condition.

2.3. Procedure

All tasks and measures were administered on a one-on-one basis over three sessions, spaced at least two days apart. During the first session, the TAI was administered first, followed by a practice version (24 trials) of the experimental task. In the remaining sessions, the experimental task was administered under high or low situational stress conditions. The order of presentation of the two conditions was counterbalanced across participants. The practice task was administered in a separate session to minimize the influence of practice task performance on children’s state anxiety and achievement on the experimental task.

In both high and low situational stress conditions, participants first completed a pre-test version of the STAIC. Then, participants received a set of task instructions corresponding to the experimental condition that they had been assigned to. After that, the experimental task was administered. To ensure that the mental arithmetic and memory recall tasks were given equal priority, participants were told to maintain a high level of accuracy on both tasks. Upon completion of the experimental task, participants completed the post-test version of the STAIC.

3. Results

3.1. Data analysis procedure

Our main dependent measures were mental arithmetic accuracy and response time (RT) as well as memory recall accuracy and RT. Accuracy scores were used as measures of effectiveness whereas accuracy divided by RT (summed across all accurate trials) was used as measures of efficiency.

Path analyses were conducted using MPlus version 7 (Muthen & Muthen, 1998-2012). Separate path models (see Figure 1) were constructed for accuracy and efficiency because anxiety-related deficits were
expected to have primary effects on efficiency, but not accuracy (Eysenck & Calvo, 1992; Eysenck et al., 2007). State anxiety was modeled using a variable that indexes the change in state anxiety from pre-test to post-test. The change in state anxiety was modeled as being affected jointly by trait test anxiety and situational stress. WM load was represented by two dummy variables, with the low WM load condition as the reference group. Experimental order refers to the order in which participants were administered the high and low situational stress conditions. It was included as a methodological control.

To test Hypothesis 1a, we estimated the conditional indirect effects of trait test anxiety on mental arithmetic task performance using the Sobel method to calculate the standard errors for the indirect effects (Muthen & Muthen, 2014). We are aware that bootstrapping procedures are preferred for the calculation of standard errors. However, these options were not suitable as our research design involved within-subjects variables.

We tested whether WM load moderated the indirect effect of trait test anxiety on arithmetic performance (Hypothesis 2) by modeling a unidirectional path from memory recall to arithmetic performance (see Figure 1). However, directionality of the relation between the two tasks may be more complex. Given our experimental procedure in which the arithmetic task is sandwiched between the presentation and recall components of the memory recall task, WM resources are required to handle the demands of both tasks. More specifically, while participants were engaged in the process of rehearsing the memory load stimuli, fewer resources would have been available to compute the solution to the arithmetic problem. To perform well, participants had to either share or shift WM resources across the two tasks. We tested a model that included a reciprocal relation between memory recall and arithmetic performance. Although a similar experimental setup had been used in previous studies, the potential reciprocal relation was typically ignored with performances on the two tasks analyzed separately. Including the reciprocal relations potentially provides a more accurate model of their effects.
3.2. **Preliminary analyses**

As a manipulation check, the effect of the situational stress manipulation on state anxiety was analysed using a 2 (situational stress: low vs. high) x 2 (time: pre-test vs. post-test) repeated-measures ANOVA. Significant main effects of situational stress and time were qualified by a significant 2-way interaction, $F(1, 127) = 24.85, p < .001$. Follow-up tests showed that there were larger increases in state anxiety levels in the high situational stress condition ($M_{\text{pre-test}} = 30.39, SD = 6.14$; $M_{\text{post-test}} = 35.61, SD = 9.15$) compared to the low situational stress condition ($M_{\text{pre-test}} = 30.53, SD = 7.14$; $M_{\text{post-test}} = 31.48, SD = 8.12$). These results indicate that our experimental manipulation had its intended effect.

Data screening for multivariate outliers using Mahalanobis distance ($p < .001$) was conducted separately for the accuracy and efficiency measures. For mental arithmetic and memory recall accuracy, seven cases were identified as multivariate outliers and deleted, leaving 121 cases for analysis. For the corresponding efficiency measures, three cases were identified and deleted, leaving 125 cases for analysis. Tables 1 and 2 present the descriptive statistics and bivariate correlations among the study variables.

Path models that specified a reciprocal relation between memory recall and mental arithmetic task accuracy and efficiency provided a better fit than did models that specified a unidirectional relation, $\chi^2_{\text{diff}} = 16.89, p < .01$ and $\chi^2_{\text{diff}} = 52.93, p < .01$ for the accuracy and efficiency models respectively. Experimental order had no effects on all measures of accuracy, efficiency and state anxiety change.
Table 1

*Descriptive Statistics and Pearson’s Product-Moment Correlation Matrix between the Anxiety and Accuracy Measures at Low and High Situational Stress Conditions (N = 121)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>SD</th>
<th>1</th>
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<th>5</th>
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<tr>
<td><strong>Low situational stress</strong></td>
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<tr>
<td>1 Trait test anxietya</td>
<td>43.69</td>
<td>10.95</td>
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<tr>
<td>2 StateChange</td>
<td>0.88</td>
<td>6.16</td>
<td>0.146</td>
<td>—</td>
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</tr>
<tr>
<td>3 MathAcc_Low</td>
<td>21.81</td>
<td>2.24</td>
<td>-0.210*</td>
<td>-0.003</td>
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<tr>
<td>4 MathAcc_Medium</td>
<td>21.79</td>
<td>2.40</td>
<td>-0.149</td>
<td>-0.059</td>
<td>0.634**</td>
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<tr>
<td>5 MathAcc_High</td>
<td>21.42</td>
<td>2.55</td>
<td>-0.280**</td>
<td>-0.085</td>
<td>0.566**</td>
<td>0.703**</td>
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<tr>
<td>6 MemAcc_Low</td>
<td>23.34</td>
<td>0.70</td>
<td>-0.090</td>
<td>0.021</td>
<td>0.151</td>
<td>0.073</td>
<td>-0.008</td>
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<tr>
<td>7 MemAcc_Medium</td>
<td>21.66</td>
<td>1.98</td>
<td>-0.116</td>
<td>-0.143</td>
<td>0.274**</td>
<td>0.256**</td>
<td>0.414**</td>
<td>0.243**</td>
<td>—</td>
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<tr>
<td>8 MemAcc_High</td>
<td>12.92</td>
<td>5.12</td>
<td>-0.216*</td>
<td>-0.143</td>
<td>0.326**</td>
<td>0.357**</td>
<td>0.474**</td>
<td>-0.044</td>
<td>0.395**</td>
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<tr>
<td><strong>High situational stress</strong></td>
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<td>1 Trait test anxietya</td>
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<tr>
<td>2 StateChange</td>
<td>4.88</td>
<td>7.28</td>
<td>0.117</td>
<td>—</td>
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<tr>
<td>3 MathAcc_Low</td>
<td>21.52</td>
<td>2.06</td>
<td>-0.202*</td>
<td>-0.019</td>
<td>—</td>
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</tr>
<tr>
<td>4 MathAcc_Medium</td>
<td>21.42</td>
<td>2.31</td>
<td>-0.236**</td>
<td>0.014</td>
<td>0.533**</td>
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</tr>
<tr>
<td>5 MathAcc_High</td>
<td>20.90</td>
<td>2.42</td>
<td>-0.274**</td>
<td>-0.090</td>
<td>0.561**</td>
<td>0.630**</td>
<td>—</td>
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<td></td>
</tr>
<tr>
<td>6 MemAcc_Low</td>
<td>23.22</td>
<td>0.96</td>
<td>-0.132</td>
<td>-0.007</td>
<td>0.079</td>
<td>0.180*</td>
<td>0.155</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 MemAcc_Medium</td>
<td>20.77</td>
<td>2.22</td>
<td>-0.199*</td>
<td>0.065</td>
<td>0.089</td>
<td>0.261**</td>
<td>0.360**</td>
<td>0.236**</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>8 MemAcc_High</td>
<td>13.27</td>
<td>4.64</td>
<td>-0.324**</td>
<td>-0.120</td>
<td>0.076</td>
<td>0.293**</td>
<td>0.359**</td>
<td>0.151</td>
<td>0.541**</td>
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</tbody>
</table>
Note. StateChange = state anxiety change score; MathAcc = mental arithmetic task accuracy; MemAcc = memory recall task accuracy. The suffixes Low, Medium and High at the end of the accuracy variable names refer to low, medium and high working memory load conditions, respectively. The possible range of scores for each variable is as follows: Trait test anxiety: 20 to 80, StateChange: -40 to 40, all accuracy variables: 0 to 24.

*Trait test anxiety was measured only once in the first experimental session.

*p < .05. **p < .01.
Table 2

Descriptive Statistics and Pearson’s Product-Moment Correlation Matrix between the Anxiety and Efficiency Measures at Low and High Situational Stress

Conditions \((N = 125)\)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Low situational stress</th>
<th></th>
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<th></th>
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Note. StateChange = state anxiety change score; MathEff = mental arithmetic task efficiency; MemEff = memory recall task efficiency. The suffixes Low, Medium and High at the end of the efficiency variable names refer to low, medium and high working memory load conditions, respectively. The possible range of scores for each variable is as follows: Trait test anxiety: 20 to 80, StateChange: -40 to 40, all efficiency variables: 0 to $\infty$.

*Trait test anxiety was measured only once in the first experimental session.

*p < .05. **p < .01.
3.3. Results of path analyses

As shown in Figure 3, our findings provided more support for Hypothesis 1b (i.e., the direct hypothesis) than for 1a. Trait test anxiety significantly affected mental arithmetic accuracy and efficiency. For both accuracy and efficiency models, all the component paths of the moderated mediation effect were not statistically significant with the exception of the path from situational stress to state anxiety change.

Figure 3. Path models showing standardized path coefficients for the measures of accuracy (top panel) and efficiency (bottom panel). WM Load = working memory load. Situational stress was coded as 0 = low situational stress condition, 1 = high situational stress condition. For the paths representing the main effect of WM load and the interaction of trait test anxiety with WM load, the coefficient printed above the path reflects the effect of the dummy variable comparing high to low load (or the corresponding interaction contrast), and the coefficient printed below the path reflects the effect of the dummy variable comparing medium to low load (or the corresponding interaction contrast). Non-significant variables and paths were omitted for simplicity.
Hypothesis 2 states that performance on the memory recall task mediates the link between trait test anxiety and mental arithmetic performance, particularly at higher levels of WM load. This hypothesis was partially supported by the accuracy data. Specifically, we found that trait test anxiety had a negative indirect effect – through memory recall accuracy -- on mental arithmetic accuracy at high WM load (conditional indirect effect = -.01, \( p < .05 \)). In contrast, there was no indirect effect of trait test anxiety at medium WM load. For measures of efficiency, only a significant main effect of WM load was found, indicating lower efficiency at high and medium (relative to low) WM load.

4. Discussion

We found a direct effect of trait test anxiety on mental arithmetic task performance. This is in line with the ACT’s emphasis on the effects of trait anxiety on cognitive performance. Although many studies have demonstrated the direct influence of trait anxiety on various aspects of cognitive processing, the majority of these studies involved adults and few studies have examined the potential interactions between trait and state anxiety. Our study is one of the first to demonstrate that a similar pattern of findings can be found in children. An important and novel contribution of our study is the inclusion of both trait test anxiety and an experimental manipulation of state anxiety, which enabled us to systematically consider the independent and joint contributions of trait test anxiety and state anxiety. This design allows us to demonstrate clearly that the effect of trait test anxiety on cognitive performance is not mediated by state anxiety.

Although our findings showed no evidence of a mediation role for state anxiety, the role of state anxiety should not be too quickly discounted. Recent evidence from the neuroscience literature (Bishop, 2009; Bishop, Jenkins, & Lawrence, 2007) has shown that heightened state anxiety is associated with increased activity in brain regions involved in threat detection (e.g., amygdala) whereas trait anxiety is related to decreased activity in regions involved in the control of attention in the presence of competing stimuli (e.g., prefrontal cortex). Consistent with these findings, a recent behavioral study found that state anxiety heightened the alerting and orienting attentional processes whereas trait anxiety was linked to deficits in the executive control network (Pacheco-Unguetti et al., 2010). If it is the case that trait and state anxiety affects
different aspects of attentional processing, it is possible that state anxiety will have stronger effects on tasks that place heavier demands on the alerting or orienting system. Indeed, Ursache and Raver (2014) found that state anxiety was associated with higher executive functioning, as measured by the Stroop task. Based on the mechanism of heightened alerting and orienting attention, the authors reasoned that higher state anxiety may help children to focus and perform better on the Stroop task. Our experimental task did not include manipulation of these systems. An interesting area for future research is to explore the effects of trait and state anxiety on a range of tasks that tap on different aspects of cognitive functioning.

We showed that the adverse effect of trait test anxiety on mental arithmetic accuracy was related to high trait test-anxious children’s poorer memory recall accuracy. This effect was particularly salient when the demands of the memory recall task were high. Children with high trait anxiety were less accurate on both the memory load and arithmetic tasks when WM demands on the former were high. This pattern of findings is consistent with the ACT and recent findings (Owens et al., 2014; Visu-Petra et al., 2011) showing that high-anxious children’s effectiveness can be impaired if the task requires higher levels of executive control because they have insufficient WM resources to handle the task demands. Interestingly, the accuracy findings were not replicated in the efficiency measures. WM load had only a main effect on memory recall efficiency: children’s response times on the memory recall task were significantly slower at high load. In other words, trait test anxiety impaired mental arithmetic efficiency regardless of the WM demands of the memory recall task. This is in line with previous findings showing anxiety-related impairments on task efficiency at low as well as high levels of WM load (Hadwin et al., 2005; Visu-Petra et al., 2011). Although less likely, it is possible that in our study, having to maintain information in memory while performing mental arithmetic imposed a greater demand on children’s WM resources even at low WM load than if the task was performed by itself.

An interesting finding that emerged from this study is the reciprocal relation between memory recall and mental arithmetic task performance. Memory recall accuracy positively affected arithmetic accuracy and vice versa; the same pattern was observed on efficiency measures. Stated differently, our results indicate that participants who responded more accurately and were more efficient on the memory recall task did likewise for the arithmetic task. Model fit comparisons also indicate that the reciprocal relations model provide a
significantly better fit to the data compared to the unidirectional model. We attribute this pattern of findings to our experimental setup in which the arithmetic task was sandwiched in between the memory task components. From a measurement point of view, our current findings highlight one of the advantages of assessing accuracy on the memory recall and arithmetic tasks separately rather than using a joint accuracy measure (e.g., see Ng & Lee, 2010). Using the latter imposes a higher performance threshold and only admits a response when participants are correct on both tasks. This would mask any effects that influence only one or the other task.

A potential critique of our study is that the level of stress elicited in our study is not comparable to the level of stress experienced in a real-life examination. In our study, post-test state anxiety scores in the high and low situational stress conditions differed by 4.6 points. In comparison, Lewis, Nikolova, Chang and Weekes (2008) and Kofman, Meiran, Greenberg, Balas and Cohen (2006) reported a difference of 4.8 points ($M_{LowStress} = 32.8; M_{HighStress} = 37.6$) and 2.1 points ($M_{LowStress} = 31.2; M_{HighStress} = 33.3$), respectively in their studies involving a naturalistic stressor (i.e., school examination). Taken together, these findings provide some assurance that the high situational stress condition is as stressful as a real-life examination. Another potential limitation is the assessment of state anxiety levels using a self-report instrument that is susceptible to response biases. Although our results indicate that the situational stress manipulation was successful in eliciting higher levels of state anxiety in the high situational stress condition, the use of physiological indices of state anxiety (e.g., salivary cortisol) would help supplement the self-report measures.

Another issue of concern is the potential cross-over effect of the situational stress manipulation (e.g., lingering feelings of state anxiety in the high situational stress condition affects performance in the low situational stress condition). Given that our manipulation check revealed a larger increase in state anxiety at the high, relative to low, situational stress condition, this is unlikely to be an issue in this study. Furthermore, the use of a mix of positive and negative feedback, together with a fourth block of trials with a larger proportion of positive feedback trials, would likely have attenuated feelings of anxiety that resulted from the negative feedback.
Findings based on the loading paradigm only identify the central executive as the WM component most adversely affected by test anxiety. It does not shed light on which central executive functions are most affected by anxiety (Eysenck et al., 2007). It has been proposed that performance on tasks based on the loading paradigm reflects rapid task switching between the mental arithmetic and memory recall task components (Eysenck et al., 2007). Thus, according to the ACT, anxiety-related decrements in WM task performance may be due to impaired task switching abilities or attentional control in anxiety. Future studies should examine this hypothesis using direct manipulations of demands on switching and attentional control.

Our study demonstrates that the adverse impact of trait test anxiety on cognitive performance is evident even in young children. This finding underscores the importance of developing effective interventions to ameliorate test anxiety in the early years, failing which these children may be at risk for future academic difficulties. Our finding that anxiety-related deficits are particularly salient at high levels of WM load suggests that interventions that improve WM resources would impact positively on performance outcomes. Although the efficacy of existing interventions is controversial (e.g., Melby-Lervåg & Hulme, 2013), Roughan and Hadwin’s (2011) pilot study showed that WM training led to positive changes in WM and self-report test anxiety in 12-year-olds who experience social, emotional and behavioral difficulties in school. These findings serve as a useful starting point for future intervention-based studies.

5. Conclusions

The current study enhances our understanding of the relative contributions of trait test anxiety and state anxiety on children’s WM performance. By employing an experimental manipulation of situational stress, we were able to systematically show that the adverse effects of trait test anxiety on WM performance is direct and not mediated by state anxiety. Our study also demonstrates clearly that the adverse effects of trait test anxiety on efficiency are independent of the task’s WM demands. In contrast, anxiety-related deficits in effectiveness occur only at high WM load. It remains for future research to investigate the extent to which these findings apply to tasks requiring different aspects of executive control and attention.
References


Acknowledgements

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