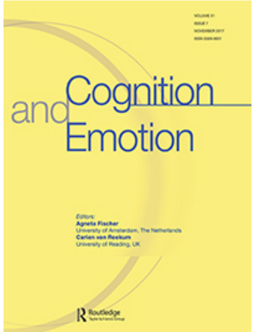

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BRIEF ARTICLE

A better state-of-mind: deep breathing reduces state anxiety and enhances test performance through regulating test cognitions in children

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ABSTRACT

A pre-test/post-test, intervention-versus-control experimental design was used to examine the effects, mechanisms and moderators of deep breathing on state anxiety and test performance in 122 Primary 5 students. Taking deep breaths before a timed math test significantly reduced self-reported feelings of anxiety and improved test performance. There was a statistical trend towards greater effectiveness in reducing state anxiety for boys compared to girls, and in enhancing test performance for students with higher autonomic reactivity in test-like situations. The latter moderation was significant when comparing high-versus-low autonomic reactivity groups. Mediation analyses suggest that deep breathing reduces state anxiety in test-like situations, creating a better state-of-mind by enhancing the regulation of adaptive-maladaptive thoughts during the test, allowing for better performance. The quick and simple technique can be easily learnt and effectively applied by most children to immediately alleviate some of the adverse effects of test anxiety on psychological well-being and academic performance.

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Test anxiety; intervention; deep breathing; state anxiety; self-regulation

Test anxiety is characterised by affective, cognitive, and behavioural responses – such as nervousness, worry and avoidance behaviours – accompanying fears of poor performance in exams or similar evaluative situations (Zeidner & Matthews, 2005). Trait test anxiety refers to the stable, dispositional tendency to perceive tests or similar evaluative situations as threatening. Individuals high in trait test anxiety tend to respond to such situations with the more transient state test anxiety. Test anxiety can adversely impact psychological well-being and performance. Over time, low self-efficacy and avoidance may arise, contributing to poorer skills/knowledge/performance, exacerbating test anxiety. Linked to correlates from depression to poor academic achievement (e.g., Ergene, 2003; Macher et al., 2012), test anxiety can artificially depress children's test performance, limiting subsequent educational and career opportunities and threatening the validity of achievement testing.

Trait test anxiety is typically reflected on scales such as the Test Anxiety Inventory (TAI; Spielberger, 1980), comprising subscales measuring affective and cognitive dimensions of test anxiety. Originally developed for use with high-school/college students, it has also been used with children as young as age 10 (e.g., Ng & Lee, 2010). Scales for younger children, such as the Children's Test Anxiety Scale (CTAS; Wren & Benson, 2004), frequently include additional dimensions such as Off-task behaviours. Affective responses are said to feature more strongly in young children, who also relate more to somatic responses than to resultant emotions (Wren & Benson, 2004). The affective subscale in the CTAS, for instance, lists somatic responses (e.g., "my hands shake") rather than emotional interpretations of physiological symptoms (e.g., "I feel panicky"; TAI). State test anxiety is typically measured on scales assessing transitory anxiety states (e.g., feelings of apprehension/tension/worry), such as the State-Trait Anxiety Inventory for Children, S-Anxiety Scale (STAIC-S; Spielberger & Edwards, 1973). The STAIC-S assesses state anxiety when administered under standard instructions, and state test

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anxiety when administered under real/imagined test conditions. Although females tend to report higher levels of anxiety, meta-analyses show the anxiety-performance relationship to be comparable across gender, and for state versus trait anxiety (see Zeidner, 1998).

Estimated to afflict 10–40% of students from age 7 (von der Embse, Barterian, & Segool, 2013), early test-anxiety intervention is warranted. Interventions from study skills training to exercise have been found to reduce test anxiety, often accompanied by improvements in test performance/achievement (e.g., Ergene, 2003; Larson, El Ramahi, Conn, Estes, & Ghibellini, 2010). However, with few exceptions (e.g., Carsley, Heath, & Fajnerova, 2015; Larson et al., 2010), most intervention studies are based on older participants, involving complex techniques requiring considerable time "in therapy" (see von der Embse et al., 2013; Ergene, 2003). Self-regulatory tools that can be easily applied to immediate effect by children were rarely studied. The few examined include a mindfulness-based colouring activity, which reduced anxiety before a spelling test in fourth-to-sixth-graders (Carsley et al., 2015). Other studies with older participants found writing about exam worries to boost performance in college and ninth-grade students (e.g., Ramirez & Beilock, 2011).

One potential self-regulatory tool easily accessible to children is deep breathing: slow, diaphragmatic breathing in which air is directed to the belly. In test anxiety research, breathing, a natural and cost-free technique that can be easily taught and applied in classrooms, is predominantly examined in combination with other techniques taught over a few sessions/weeks (e.g., Larson et al., 2010). Of the few exceptions, Brunyé et al. (2013) found 15 min of focused attention breathing to enhance calmness and arithmetic performance, but in older math–anxious college students. Applicable in a self-directed manner, deep breathing is more accessible than a colouring/writing activity – not always feasible before a test without the direction of a teacher. However, whether and how simply breathing can immediately regulate anxious feelings and performance – and in children – has yet to be examined.

Deep breathing is expected to directly reduce feelings of anxiety. Respiratory patterns are closely related to affective and autonomic arousal states: quick, shallow, thoracic breathing with anxiety, tension and unpleasant affect; slow, deep, abdominal/diaphragmatic breathing with relaxation and pleasant affect (Boiten, Frijda, & Wientjes, 1994). With physiological effects contrary to autonomic arousal and hyperventilation, deep breathing promotes a state of relaxation and is commonly included in the management of anxiety-related symptoms in anxiety disorders.

How deep breathing impacts performance may be more complex. Test-anxious individuals have been found to have poorer inhibitory-control-of-attention to external (e.g., visual distractors) and internal salient, task-irrelevant stimuli (e.g., worry) (see Eysenck, Derakshan, Santos, & Calvo, 2007, for a discussion). They tend to report high levels of worry, which purportedly interferes with their ability to direct attention to task-focused cues/demands (Sarason, 1984), or consume cognitive resources available for task-related processing (Eysenck & Calvo, 1992). However, they also tend to report more coping/on-task thoughts (e.g., Zatz & Chassin, 1985). Eysenck and Calvo (1992) proposed that worry affects mainly performance efficiency; impact on performance effectiveness can be modulated by compensatory effort from increased motivation. Consistent with this proposal, Lyons and Beilock's (2012) neuroimaging study found that the impact of math anxiety on performance was related to the math-anxious' ability to engage top-down cognitive control resources while anticipating a math task, mediated by activity in motivation-related (e.g., task prioritisation) brain regions during the task.

Compensatory task prioritisation efforts may manifest as coping/on-task thoughts. The regulation of test cognitions – decreasing debilitative-maladaptive and/or increasing compensatory-adaptive thoughts during a test – may bring about a better state-of-mind, allowing for better performance. Originating from work in psychopathology, state-of-mind ratios typically refer to the balance between positive and negative cognitions (Schwartz & Garamoni, 1989). Previous work found state-of-mind to be related to state anxiety (e.g., Arnkoff, Glass, & Robinson, 1992). Reduced state anxiety following deep breathing may enable a better state-of-mind, ameliorating the effects of test-anxiety on performance. At the same time, attentional control in the trait-test-anxious is disrupted most commonly under anxious states (Eysenck et al., 2007). Lower state anxiety may enable better top-down inhibitory-control-of-attention to distractors such as worry, enabling better performance. It is thus hypothesised that deep breathing's effect on performance may be mediated by better state-of-mind/inhibitory-control-of-attention via deep breathing's effect on anxiety reduction. Alternatively, deep breathing may directly enhance inhibitory-control-of-attention and/or state-of-mind, or anxiety reduction may directly improve performance (i.e., the hypotheses that improved anxiety/state-of-mind/inhibitory-control-of-attention mediate deep breathing's effect on performance). Effects may also be moderated by child factors such as gender and susceptibility to the effects of test anxiety. For example, larger effects may be obtained for individuals with poorer inhibitory-control-of-attention, greater proneness to worry or autonomic reactions in test situations. Response to anxiety-reduction intervention has differed by gender in some studies (e.g., Carsley et al., 2015).

The present study is the first to examine whether: (i) taking deep breaths before a test reduces anxious feelings and improves performance in children, (ii) effects are modulated by gender and individual differences in aspects of dispositional/trait test anxiety and inhibitory-control-of-attention, (iii) deep breathing impacts performance by reducing anxious feelings, enhancing the regulation of disruptive thoughts/cognitions (i.e., improving state-of-mind), and/or improving inhibitory-control-of-attention. Mediation effects hypothesised in the preceding section are examined. In our examination of trait test anxiety, we compare the CTAS against the well-established TAI to examine if the children's scale may be a more sensitive measure for elementary school children.

Method

Participants

Primary 5 (fifth grade) students ($N = 154$) from four elementary schools attended Session 1 with informed parental and child consent. Students were percentile-split on their trait-test-anxiety scores (see Procedure) into High/Mid/Low trait-test-anxiety bands and randomly assigned to intervention/control groups for Session 2, balancing for anxiety band, school and gender. After accounting for absentees, withdrawals, corrupted data, and participants observed to be non-compliant ($n = 20$, 2, 3 and 7, respectively), the final data set contained 122 participants (63 boys, $\text{Mean}_{age} = 10.67$, $SD = 0.37$). Sample size calculations based on Thoemmes, MacKinnon, and Reiser (2010) allowed for at least 80% power for medium-sized two-stage-mediation effects – our most power-demanding analysis. We report how we determined our sample size, all data exclusions, manipulations, and measures in the study. Ethics approval was obtained from the author's university institutional review board.

Measures

Trait test anxiety

The TAI requires participants to rate how frequently they experience each of 20 symptoms of anxiety in tests and examinations. Cognitive and affective dimensions are indexed by the Worry (8 items, e.g., "Thoughts of doing poorly interfere with my concentration on tests") and Emotionality (8 items, e.g., "I feel very nervous when taking an important test") subscale scores. The scales demonstrated good internal-consistency reliabilities in our sample ($\alpha = .79$ to .90). In the CTAS, developed for children grades 3–6, participants rate how well each of 30 items "describing how students may think, feel or act while they are taking tests" describe them. The Autonomic-Reactions, Thoughts, and Off-task-Behaviours subscales, respectively, assesses proneness to somatic responses (9 items, e.g., "My heart beats fast"), worry/self-critical/test-irrelevant thoughts (13 items, e.g., "I wonder if I will pass"), and nervous habits/ distracting behaviours (8 items, e.g., "I play with my pencil or pen") during tests. Good internal-consistency reliabilities were achieved ($\alpha = .82 - .95$). Both scales employ a 1 (almost never) to 4 (almost always) Likert scale.

State test anxiety

In the STAIC-S, participants select one of three choices on 20 statements describing how they feel "right now, at this very moment" (e.g., "very nervous/nervous/not nervous"). Higher scores reflect greater anxiety (range: 20–60). Internal-consistency reliabilities were high ($\alpha = .91 - .92$).

Test performance

A timed math computational test was adapted from the Wechsler Individual Achievement Test–Third Edition (WIAT–III; Weschler, 2009) Math Fluency test. The final Addition and Subtraction subtests each contained 48 problems at a 60-second time limit; Multiplication contained 20 problems at a 30-second time limit. As per WIAT-III instructions, participants were required to follow the order of presentation (increasing difficulty) in each subtest, without skipping any problem. The dependent measure was total math score.

Thoughts

In the revised Children's Cognitive Assessment Questionnaire (CCAQ; Zatz & Chassin, 1985), participants rate how frequently each thought item on five subscales occurred during the test on a 1 (never) to 4 (all the time) Likert scale: Positive self-evaluations (10 items; e.g., "I'm bright enough to do this"), Negative self-evaluations (10 items; e.g., "I'm too dumb to do this"), On-task thoughts (7 items; e.g., "Answer every question"), Off-task thoughts (10 items; e.g., "I am hungry"), and Coping thoughts (10 items; e.g., "Try to calm down"). Good internal-consistency reliabilities were demonstrated ($\alpha = .76 - .90$) with the exception of On-task thoughts ($\alpha = .61 - .76$; possibly due to fewer items). State-of-mind indices in the psychopathology literature are typically based on scales comprising only positive/negative thoughts. As the CCAQ included more categories, we calculated our state-of-mind index as the proportion of adaptive thoughts (total Positive, On-task, and Coping thoughts) over total (adaptive-plus-maladaptive) thoughts.

Inhibitory-control-of-attention

A computerised flanker-like, distractor interference task was adapted from Forster and Lavie (2008). On each trial, participants viewed a centralised circle comprising a target letter – "X"/ "N" – and five lowercase "O"s. Participants identified the target letter by keypress, as quickly as they correctly can, ignoring any distractors outside the centralised circle. On some trials, a distractor "X"/"N" appeared to the left/right of the ring, and may be congruent (e.g., target "X", distractor "X") or incongruent (e.g., target "X", distractor "N") with the target. Though typically called task-irrelevant distractors in the literature, we classify them as "task-relevant distractors" after Forster and Lavie (2008), who argued that though their locations are task-irrelevant their identities make these distractors highly task-relevant. On some trials, one of six coloured cartoon characters appeared at the top/bottom of the ring. These were "task-irrelevant distractors" whose identities did not overlap with possible target responses. Participants completed 12 practice trials before four experimental blocks comprising 2 warm-up trials (discarded in analysis) and 24 each of congruent-, incongruent-, irrelevant- and no-distractor trials, in equal proportions. Trials were presented in a pseudo-randomised order, balanced for trial-type, stimulus and position.

A larger task-relevant-interference effect (mean incongruent RT minus mean congruent RT), reflecting poorer inhibitory-control-of-attention, has been found with high trait-anxious individuals (e.g., Bishop, 2009). Little research has explored whether test anxiety is associated with interference from task-irrelevant-but-attention-attracting distractors, which Forster and Lavie (2008) argued is more relevant to distractibility in everyday life. Task-irrelevant-interference was derived by subtracting mean no-distractor RT from mean task-irrelevant-distractor RT. Spearman-Brown Split-half coefficients between .83 and .94 for each trial type's mean RT indicated good internal-consistency reliability.

Procedure

Participants were tested in their respective schools. Session 1 participants were administered the TAI followed by the longer CTAS in a classroom (~30 min). For Session 2 (~1 h), intervention and control groups in each school were tested concurrently but separately in two computer labs, each led by an experimenter with a team of research assistants trained to help with task administration. The experimenters followed identical scripts and protocol, except where the intervention was involved. Each research assistant sat between two participants.

To create an anxious, evaluative situation, the students were told they were being tested on their math and attention skills; they needed to score as many correct answers as possible within the time limits; their results would be openly compared with the other students; a countdown timer will be displayed and a buzzer will sound when the time was up for each math subtest. The STAIC-S was administered, followed by the Addition, Subtraction and Multiplication subtests, the CCAQ, and the inhibitory-control-of-attention task. There were one-minute rest breaks after the Addition and Subtraction subtests, and after each block in the inhibitory-control-of-attention task. A 10-minute break followed. The intervention group learnt and practiced deep breathing, placing their palms on their lower abdomens, focusing on directing air into their bellies and watching/feeling the rise-and-fall with each inhalation/exhalation. The research assistants guided where necessary. Control group participants rested with no specified activity.

The post-test cycle was administered as per the pre-test. Parallel forms for the math tests were used. Questionnaire items and task trials were presented in different orders. The intervention group practiced deep breathing during all breaks. Participants who were not engaged with the deep breathing – observable by the rise-and-fall of the abdomen – despite prompts and encouragement, were marked as non-compliant and excluded from data analysis ($n = 7$). This minimised the dilution of true intervention effects.

Participants were debriefed before dismissal. It was emphasised that the tasks were not real tests; their performance will not be openly evaluated/compared.

Results

Intervention and control groups showed no significant mean differences, except for slightly higher number of coping thoughts and larger task-irrelevant-interference at pre-test in the control group (Table 1). Unless otherwise stated, statistical significance was evaluated at $\alpha = .05$.

To examine whether taking deep breaths before a test reduced anxious feelings and improved performance, separate 2 (Time: pre-test vs. post-test) × 2 (Intervention: control vs. intervention) repeated measures analyses of variance were conducted for state anxiety and math performance. Significant interactions on both state anxiety [$F_{1,119} = 5.21$, MSE = 14.41, $\eta\rho^2 = .04$, $p = .02$] and math performance [$F_{1,117} = 4.19$, MSE = 20.08, $\eta\rho^2 = .04$, $p = .04$] indicated greater improvements for the intervention group: Although both groups significantly improved from pre- to post-tests, the intervention group showed a larger decrease in anxiety ratings [11% vs. 4% ($d = .73$ vs. .24); $t(119) = 2.28$, $p = .02$, $d = .42$], and a larger increase in math scores [13% vs. 9% ($d = 1.33$ vs. .90); $t(117) = 2.05$, $p = .04$, $d = .38$]. To test for modulation by gender, we repeated the analyses with Gender (male vs. female) included. The Time × Intervention × Gender interaction was insignificant for math [$F_{1,115} = .71$, MSE = 20.28, $\eta\rho^2 = .01$, $p = .40$] but marginally significant for anxiety [$F_{1,117} = 3.10$, MSE = 14.15, $\eta\rho^2 = .03$, $p = .08$]: Anxiety significantly decreased in both groups of females [9% vs. 8% ($d = 1.21$ vs. .37); $t(47.3) = .33$, $p = .74$, $d = .01$], but only in the intervention group for males [13% vs. 1% ($d = .56$ vs. .03); $t(61) = 2.84$, $p = .01$, $d = .71$].

To examine whether the intervention's effects were modulated by dispositional variables, we first ran a hierarchical regression analysis with anxiety reduction as criterion. Dummy-coded Intervention group and centred TAI-total-score were entered as predictors in the first step; their interaction term in the second. Analyses were repeated with TAI-total-score replaced by TAI-Emotionality, TAI-Worry, CTAS-total-score, CTAS-Thoughts, CTAS-Autonomic-Reactions, CTAS-Off-task-Behaviours, and pre-test task-relevant-interference and task-irrelevant-interference. Parallel analyses were performed with math improvement as criterion. The only moderation observed was a marginally significant interaction between CTAS-Autonomic-Reactions and Intervention on math improvement [$R^2 = .06$, $F_{3,114} = 2.53$, $p = .06$; $\Delta R^2 = .03$, $\Delta F_{1,114} = 3.60$, $p = .06$; $\beta = .23$, $p = .06$]. We investigated this trend by comparing students scoring the top and bottom thirds on the CTAS-Autonomic-Reactions subscale. Average per-item-ratings for the two groups (1.2 vs. 2.8) corresponded approximately to "Almost never" and "Most of the time", respectively. A 2 (Intervention: intervention vs. control) × 2 (Autonomic-Reactions: high vs. low) ANOVA on math improvement showed a significant interaction [$F_{1,79} = 4.41$, MSE = 42.36, $\eta\rho^2 = .05$, $p = .04$]. Low autonomic-reactive students improved to a similar degree in both control/intervention groups [$t(41) = -.14$, $p = .89$, $d = .04$]. Intervention-group high autonomic-reactive students improved significantly more than controls [17% vs. 7% ($d = 1.59$ vs. .90); $t(38) = 2.85$, $p = .01$, $d = .90$].

We explored possible routes from intervention to performance using Mplus 7 (Muthén & Muthén, 1998–2012). Indirect effects were tested with bias-corrected bootstrapped confidence intervals (95%) based on 5000 draws. Separate single-stage mediation models (Figure 1(a)) tested the hypotheses that deep breathing improved math performance indirectly through (i) reducing state anxiety (Model 1), (ii) improving attentional control in terms of reducing task-relevant-interference (Model 2), or (iii) improving attentional control in terms of reducing task-irrelevant-interference (Model 3). Mediation effects were not significant. Other than the direct effects of intervention on anxiety and math in all the models, there was a significant negative path from intervention to task-irrelevant-interference reduction in Model 3 – likely due to the control group's higher pre-test task-irrelevant-interference, resulting in the larger decrease. Reduction in task-irrelevant-interference was hence not meaningful in the context of the intervention's effects and was excluded from subsequent analyses. A two-stage mediation where the intervention improved inhibitory-control-of-attention (task-relevant-interference reduction) via reducing state anxiety was also not significant (Model 4; Figure 1

Table 1. Descriptive statistics of measures across intervention and control groups.

Measure	Mean (SD)		95% CI		Range	
	Control	Intervention	Control	Intervention	Control	Intervention
Session 1						
TAI	44.40 (11.96)	44.45 (12.22)	[41.49, 47.32]	[41.15, 47.76]	25.00–78.00	22.00–73.00
Emotionality	18.49 (5.67)	18.27 (5.64)	[17.11, 19.87]	[16.75, 19.80]	9.00–32.00	8.00–32.00
Worry	16.81 (5.13)	16.80 (5.33)	[15.56, 18.06]	[15.36, 18.24]	8.00–32.00	8.00–31.00
CTAS	68.97 (19.92)	65.44 (21.20)	[64.11, 73.83]	[59.70, 71.17]	31.00–116.00	31.00–102.00
Thoughts	32.91 (10.90)	31.85 (11.28)	[30.25, 35.57]	[28.80, 34.90]	14.00–52.00	13.00–51.00
Autonomic reactions	17.84 (6.29)	16.65 (6.21)	[16.30, 19.37]	[14.98, 18.33]	9.00–35.00	9.00–31.00
Off-task behaviours	18.22 (5.64)	16.93 (5.86)	[16.85, 19.60]	[15.34, 18.51]	8.00–30.00	9.00–30.00
Session 2 pre-test						
STAIC-S	30.55 (5.94)	32.53 (7.76)	[29.09, 32.00]	[30.43, 34.62]	20.00–44.00	20.00–51.00
Math score	67.52 (13.73)	65.20 (14.55)	[64.12, 70.93]	[61.23, 69.17]	42.00–98.00	40.00–108.00
CCAQ						
On-task thoughts	20.25 (4.12)	20.45 (3.51)	[19.25, 21.26]	[19.51, 21.4]	10.00–28.00	11.00–28.00
Off-task thoughts	20.61 (7.23)	18.87 (6.64)	[18.83, 22.38]	[17.08, 20.67]	10.00–38.00	10.00–38.00
Positive self-evaluation	24.42 (6.03)	24.36 (6.44)	[22.95, 25.89]	[22.62, 26.1]	11.00–38.00	11.00–37.00
Negative self-evaluation	16.59 (5.54)	16.85 (6.09)	[15.23, 17.95]	[15.21, 18.5]	10.00–35.00	10.00–33.00
Coping thoughts**	27.21** (6.62)	24.22** (5.90)	[25.59, 28.82]	[22.62, 25.81]	12.00–40.00	11.00–37.00
Attention						
Congruent	745.22 (114.83)	733.63 (94.73)	[717.21, 773.23]	[708.03, 759.24]	540.27–1054.00	567.16–916.58
Incongruent	810.65 (158.25)	788.49 (117.12)	[772.05, 849.25]	[756.82, 820.15]	563.76–1283.30	617.89–1093.24
Irrelevant	788.84 (130.83)	758.82 (98.37)	[756.93, 820.75]	[732.23, 785.41]	561.33–1090.62	588.82–984.95
No-distractor	675.65 (102.00)	672.67 (83.11)	[650.78, 700.53]	[650.21, 695.14]	505.39–1005.58	551.00–860.35
TRI	65.44 (74.71)	54.85 (58.53)	[47.21, 83.66]	[39.03, 70.67]	−55.32–323.64	−49.68–254.39
TII*	113.19* (70.69)	86.14* (52.00)	[95.94, 130.43]	[72.09, 100.20]	−12.44–287.62	−9.66–219.35
Session 2 Post-test						
STAIC-S	29.19 (6.39)	28.93 (7.45)	[27.63, 30.75]	[26.91, 30.94]	20.00–47.00	20.00–54.00
Math score	73.95 (14.37)	74.24 (15.29)	[70.42, 77.49]	[70.10, 78.37]	47.00–114.00	49.00–119.00
CCAQ						
On-task thoughts	21.18 (4.74)	20.60 (4.63)	[20.02, 22.33]	[19.35, 21.85]	7.00–28.00	10.00–27.00
Off-task thoughts	19.97 (7.23)	17.75 (6.90)	[18.21, 21.73]	[15.88, 19.61]	10.00–40.00	10.00–36.00
Positive self-evaluation	25.18 (7.61)	24.67 (6.68)	[23.32, 27.03]	[22.87, 26.48]	10.00–40.00	12.00–37.00
Negative self-evaluation	16.73 (6.50)	16.26 (6.04)	[15.15, 18.32]	[14.61, 17.91]	10.00–38.00	10.00–34.00
Coping thoughts	28.21 (8.17)	25.16 (7.50)	[26.22, 30.20]	[23.14, 27.19]	10.00–40.00	10.00–39.00
Attention						
Congruent	655.39 (82.14)	654.72 (76.98)	[635.03, 675.74]	[633.91, 675.53]	523.80–847.64	494.90–826.04
Incongruent	726.54 (118.41)	711.15 (88.77)	[697.43, 755.64]	[687.15, 735.15]	547.00–1118.26	532.47–875.79
Irrelevant	673.78 (90.57)	672.44 (83.46)	[651.51, 696.04]	[649.88, 695.01]	529.47–869.13	518.64–912.09
No-distractor	631.10 (83.76)	629.63 (77.30)	[610.51, 651.69]	[608.73, 650.53]	494.24–830.77	492.27–790.18
TRI	67.27 (53.20)	56.43 (43.07)	[54.09, 80.45]	[44.79, 68.07]	−34.18–312.09	−33.97–177.46
TII	42.68 (42.29)	42.82 (31.47)	[32.28, 53.08]	[34.31, 51.32]	−68.45–210.34	−14.85–156.23

Note. TAI, Test Anxiety Inventory; CTAS, Children's Test Anxiety Scale; STAIC-S, State anxiety measured on State-Trait Anxiety Inventory for Children, S-Anxiety Scale; CCAQ, revised Children's Cognitive Assessment Questionnaire; Attention, inhibitory-control-of-attention task. TRI, task-relevant interference effect (incongruent − congruent mean reaction time); TII, task-irrelevant interference effect (irrelevant − no-distractor mean reaction time). Calculated based on total scores, with the exception of the Attention task which is based on mean reaction time (ms).
*Significant difference between control and intervention group means at $p < .05$.
**Significant difference between control and intervention group means at $p < .01$.

(b)). Effects of intervention on anxiety and inhibitory-control-of-attention were not moderated by gender or trait anxiety measures. Given the lack of direct/indirect effect from intervention to inhibitory-control-of-attention, mediation via improved inhibitory-control-of-attention was unlikely and excluded in subsequent models.

We tested the hypothesis that the intervention improved performance by enhancing the regulation of disruptive thoughts/cognitions (Figure 1(c); Model 5). State anxiety reduction significantly predicted state-of-mind improvement ($b = .18$), which predicted math improvement ($b = .20$). The intervention's effect on state-of-mind was fully mediated by its effect on state anxiety (indirect effect, unstandardised = .40, BC-CI [.07, 1.03]); its effect on math improvement was partially mediated by its effect on state-of-mind via reduced state anxiety (indirect effect, unstandardised = .08, BC-CI [.01, .32]). Effects of the intervention were not moderated by gender or any measure of trait

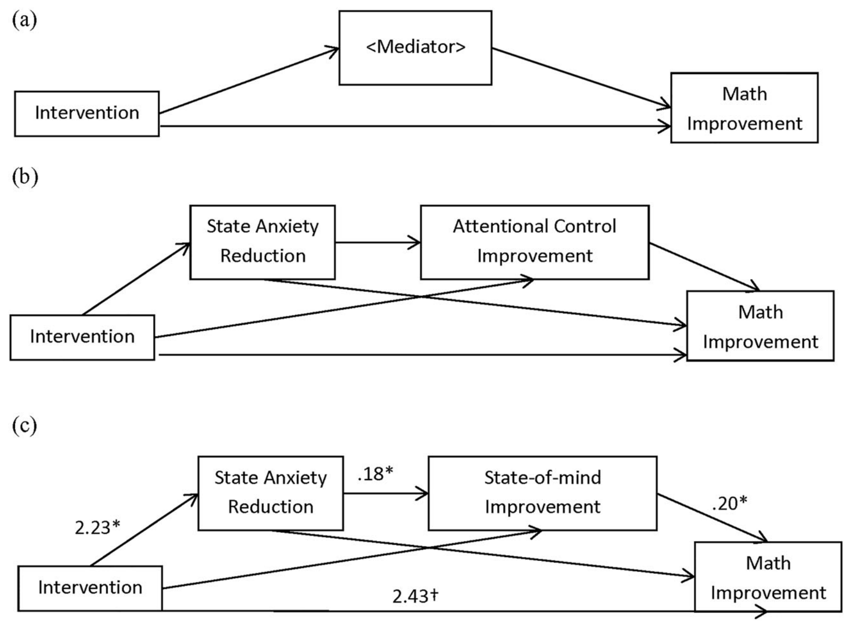

Figure 1. Hypothesised path models from intervention to improvement in math performance via the regulation of state anxiety, attention and test cognitions. (A) Separate single-stage mediation models testing the hypotheses that deep breathing intervention improved math performance indirectly through the respective mediators: state anxiety reduction (Model 1), task-relevant interference reduction (Model 2), and task-irrelevant interference reduction (Model 3). (B) Two-stage mediation model testing the hypothesis that the deep breathing intervention reduced state anxiety, which improved attentional control in terms of reducing task-relevant interference, which improved math performance (Model 4). (C) Two-stage mediation model testing the hypothesis that the deep breathing intervention reduced state anxiety, which improved overall state-of-mind, which improved math performance (Model 5). Results provided support for Model 5: The intervention's effect on math improvement was found to be partially mediated by its effect on state-of-mind via reduced state anxiety. Significant unstandardised estimates are reported in the figure. $^*p < .05$; $^\dagger p < .10$.

anxiety. This final supported model accounted for 4% of the variance in state anxiety reduction, and 5% of the variance each in state-of-mind and math improvement. As our state-of-mind measure deviated from some used in previous literature, we also checked for mediation effects with alternative mediators: improvement in positive-over-negative-self-evaluations-ratio, and reduction-in-total-thoughts. These models were not supported. Pre-post difference scores were used in all regression and mediation analyses to represent reduction/improvement.

Discussion

The present study is the first to examine the effects of simply deep breathing on anxiety and test performance in children, and their possible mechanisms and moderators. Results suggest that taking deep breaths before a test can help reduce feelings of anxiety and enhance (math) performance. Students reported substantially less anxious feelings at the start of a math test and performed better on the test when they had first taken deep breaths. Although some improvement on the post-test can be expected even without intervention, this naturally occurring improvement, as observed in the control group, was quite small. Comparatively, the degree of improvement with deep breathing was much larger. Taking a few deep breaths before a test may benefit children's well-being, in terms of their immediate psychological state and academic performance.

Although none of our moderators tested significant at $\alpha = .05$, statistical trends suggest that deep breathing may be especially helpful in reducing anxiety in boys – for girls, anxiety decreased even without intervention, albeit to a lesser extent, but boys showed substantial anxiety reduction only with intervention. Probing a trend towards greater effectiveness in enhancing test performance for students with higher autonomic reactivity revealed significant moderation when comparing high- versus low-autonomic-reactivity groups: Deep breathing was efficacious for students prone to autonomic reactions during tests/exams, but not for those who are not. That this trend was found with CTAS-Autonomic-Reactions but not TAI-Emotionality was the only disparate result in the analyses involving both CTAS and TAI subscales. The pattern of results with trait test anxiety measured on both scales was otherwise largely similar; both scales showed high internal reliability in our sample. Nonetheless, the moderation results suggests that CTAS-Autonomic-Reactions may be more sensitive in measuring the affective dimension of trait test anxiety in children than TAI-Emotionality, especially in identifying children likely to benefit (in performance) from deep breathing. Consistent with Wren and Benson's (2004) observation, physiological responses to anxiety (and their descriptors, e.g., "hands shake") are probably easier for children to identify and understand than emotional states/ their descriptions (e.g., "panicky"). Children may be taught to recognise their autonomic reactions as a cue to take deep breaths.

Although the variances explained in our final model were rather modest, results of our mediation analyses support the hypothesis that deep breathing reduces state anxiety, creating a better state-of-mind which allows for better performance in test-like situations. While our short-term intervention may have limited immediate effects on strongly trait-determined variables, it may be able to improve more state-related variables via its regulatory influence on state anxiety. The lack of an association between state anxiety and inhibitory-control-of-attention in the current study may thus partially explain why deep breathing's effect on reducing state anxiety did not significantly improve inhibitory-control-of-attention. Although both high trait and state test anxiety have been associated with poor inhibitory-control-of-attention in many studies, Pacheco-Unguetti, Acosta, Callejas, and Lupiáñez (2010) suggested that trait anxiety may be more closely related to top-down executive attention – captured by inhibitory tasks similar to that used here, and state anxiety more related to bottom-up aspects of attentional control (e.g., alerting and orienting). Reducing state anxiety may thus not improve top-down inhibitory-control-of-attention, as found in our study. At the same time, however, trait anxiety also did not modulate the effects of deep breathing on inhibitory-control-of-attention. Future investigations that differentiate between top-down and bottom-up aspects of inhibitory-control-of-attention in an intervention context may elucidate these relationships.

The modestly sized effects and variances explained in our mediation model suggest that variables not examined in the study likely also contributed to improvements. The anxiety-performance relationship is complex, implicating factors ranging from type and difficulty of task (e.g., Diaz, Glass, Arnkoff, & Tanofsky-Kraff, 2001; Lyons & Beilock, 2012), to interest and motivation (e.g., Macher et al., 2012). The present study focused on variables hypothesised to be relevant for a deep breathing intervention, based on recent findings, and on immediate effects that are possible given unchanged statuses in stable/ long-term variables (e.g., ability) unlikely to be altered by a short bout of deep breathing. Task type and difficulty were kept consistent as we were interested in improvements rather than absolute levels of performance. Nonetheless, it is possible that effects may be moderated by currently excluded factors. For example, the intervention may work better for those who are more adversely affected under evaluative versus non-evaluative situations, or for tasks requiring oral versus written presentations (Diaz et al., 2001), or in actual high-stakes versus simulated low-stakes testing situations (Segool, Carlson, Goforth, von der Embse, & Barterian, 2013).

Despite its modest effects, deep breathing is a quick and simple technique involving minimal resources or disruption. The present study demonstrates that it can be easily learnt (<10 min) and effectively used by children as young as Primary 5. Although a few children showed some difficulty/resistance (7 non-compliant), better effects may be achieved given more time and practice. It is also more accessible than previously identified techniques such as writing about exam worries – especially for younger children unable to articulate their worries through writing. Once learnt, deep breathing can become a self-regulatory tool to be applied at a child's disposal to bring about a better state-of-mind and performance in anxiety-inducing test-like situations.

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