University Library

MINERVA ACCESS

A gateway to Melbourne's research publications

Minerva Access is the Institutional Repository of The University of Melbourne

Author/s:
Hitchcock, C;Westwell, MS

Title:
A cluster-randomised, controlled trial of the impact of Cogmed Working Memory Training on both academic performance and regulation of social, emotional and behavioural challenges

Date:
2017-02-01

Citation:
Hitchcock, C. & Westwell, M. S. (2017). A cluster-randomised, controlled trial of the impact of Cogmed Working Memory Training on both academic performance and regulation of social, emotional and behavioural challenges. Journal of Child Psychology and Psychiatry and Allied Disciplines, 58 (2), pp.140-150. https://doi.org/10.1111/jcpp.12638.

Persistent Link:
https://hdl.handle.net/11343/292405

Received Date : 25-Feb-2016
Revised Date : 29-Jun-2016
Accepted Date : 05-Jul-2016
Article type : Original Article

Author Manuscript

A cluster-randomised controlled trial of the impact of cognitive training on both academic performance and regulation of social, emotional, and behavioural challenges

Caitlin Hitchcock[1,2]
Martin S. Westwell[1]

[1]Australian Research Council, Science of Learning Research Centre, Flinders University, Australia
[2] Medical Research Council, Cognition and Brain Sciences Unit, Cambridge, UK

Conflict of interest statement: No conflicts declared.

Background: We explored whether school-based Cogmed Working Memory Training (CWMT) may optimize both academic and psychological outcomes at school. Training of executive control skills may form a novel approach to enhancing processes that predict academic achievement, such as task-related attention, and thereby academic performance, but also has the potential to improve the regulation of emotion, social problems, and behavioural difficulties. **Methods:** Primary school children (Mean age = 12 years, N = 148) were cluster-randomised to complete active CWMT, a non-adaptive/placebo version of CWMT, or no training. **Results:** No evidence was found for training effects on task-related attention when performing academic tasks, or performance on reading comprehension and mathematics tasks, or teacher-reported social, emotional, and behavioural difficulties. **Conclusions**: CWMT did not improve control of attention in the classroom, or regulation of social, emotional and behavioural difficulties.

This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1111/jcpp.12638

This article is protected by copyright. All rights reserved

Keywords: Working memory training, learning, emotion regulation, behaviour regulation

Introduction

Working memory, the ability to maintain relevant information during demanding mental activities, is related to both academic achievement and the ability to maintain focused and controlled attention (Gathercole & Alloway, 2008; Lui & Tannock, 2007). Over recent years there has been widespread interest in the potential of working memory training to improve children's school-based outcomes. To date, the majority of studies in this field have focussed on the impact of training on psychometric assessments of working memory and attention, or standardised measures of learning, with mixed results (e.g. Gray et al., 2012; Holmes & Gathercole, 2014). The aim of the current study was to investigate, for the first time in a single study, whether training could improve children's on-task behaviour during academic tasks and also enhance their social, emotional, and behavioural functioning. Unlike previous studies, our focus was on the impact of Cogmed Working Memory Training (CWMT; Pearson, 2016) on both academic and psychological aspects of school functioning.

Working memory training programmes such as CWMT have been a controversial advancement in novel interventions. Training provides repeated practice of interactive computer exercises that tax working memory and executive skills, and aims to increase core cognitive capacities, such as working memory and attention, thereby rectifying cognitive deficits in individuals who experience impairment, or expanding capacity to a superior level in those individuals within the average range. In turn, increased capacity may enhance performance on tasks that require executive control. Improvement may therefore occur in learning, but also in regulation of behaviour and affect. There is substantial theoretical contention on whether it is possible to expand the targeted cognitive functions, and evidence is mixed for the efficacy of training in improving cognitive capacity in both impaired and typical samples (Gibson, Gondoli, Johnson, Steeger, & Morrissey, 2012; Melby-Lervåg & Hulme, 2013; Shipstead, Hicks, & Engle, 2012). In terms of improved capacity leading to improvement in learning, there is no impact of training on basic academic skills, such as word decoding and arithmetic (for meta-analysis see Melby-Lervåg & Hulme, 2013), though there are few studies that examine performance on reading comprehension and mathematics assessments, with mixed findings and methodological weaknesses in those that do (e.g., Holmes & Gathercole, 2014). Indeed, Cogmed asserts that further studies are needed to determine specific effects in daily life (Söderqvist & Nutley, 2016). However, it has been argued that the impact of training on everyday functioning may not exclusively occur through expanding cognitive capacity, but potentially through promoting more efficient use of

This article is protected by copyright. All rights reserved

cognitive control processes (Dunning & Holmes, 2014; Gathercole, Dunning, & Holmes, 2012). This study therefore explored whether CWMT may work as a holistic wellbeing programme through improving both a) children's control of task-related attention, and thereby academic performance, and b) the regulation of social interaction, emotion, and behaviour.

Working memory, attention, and academic performance are closely related (Gathercole & Alloway, 2008). There are a number of theories on the structure and function of working memory (see Conway, Jarrold, Kane & Trowse, 2007 for review). However, all conceptualisations agree that working memory is a system that allows the temporary storage and processing of information, and that working memory either includes an attentional component (e.g., the central executive in the model proposed by Baddeley, 2000; Baddeley & Hitch, 1974), or is embedded in a broader limited-capacity system of controlled attention (e.g., Kane, Bleckley, Conway, & Engle, 2001). In each conceptualisation, working memory and attention control are explicitly linked. Theoretically, training improvement in working memory may therefore influence the ability to control task-related attention. Task-related attention is the ability to maintain the focus of attention when completing mental activities to ensure that relevant information is acquired, and that distraction is minimised (Unsworth & Spillers, 2010). Failure in the control of task related attention, such that attention is diverted away from the task at hand, is often referred to as mind wandering (e.g., McVay & Kane, 2012), and has a negative impact on task performance (Kane et al., 2007). Indeed, both working memory and control of attention are strong predictors of academic performance (Gathercole & Alloway, 2008; Lui & Tannock, 2007). Consistent with the theoretical links between working memory and attention, the experience of mind wandering is predicted by the individual's working memory capacity, such that those with greater working memory capacity will experience fewer task-unrelated thoughts during task completion (Kane et al., 2007; McVay & Kane, 2012). Thus, a key claim made by Cogmed (2016) is that working memory training will also improve the ability to focus attention and resist distraction, which will have a cascade effect on learning outcomes for reading and mathematics.

Current literature on the impact of CWMT on attention control indicates that training improves performance on assessments of selective (e.g., Stroop task) and sustained (e.g., go/no go tasks) attention (Melby-Lervåg & Hulme, 2013; Shipstead et al., 2012). However, the capacity to maintain attention does not solely predict task-related attention in everyday settings due to other internal factors such as motivation and interest (Unsworth & McMillan, 2013), and external factors such as environmental distraction (Fisher, Godwin, & Seltman,

This article is protected by copyright. All rights reserved

Author Manuscript

2014). Further, structured assessments of attention control used to measure improvement following CWMT are also similar to the training tasks. For example, the Stroop task requires the child to attend to computerised, colourful stimuli for a number of seconds, as completed in training. As the content and procedure of psychometric assessments overlaps with training tasks, improvement on attention measures may reflect improvement in relatively task-specific strategies. Indeed, there has only been one study to show that children demonstrate improvement in attention following CWMT on a task other than the Stroop or go/no go tasks (Thorell et al., 2008), and this study did not determine if gains were maintained at a follow-up assessment. Classroom-based assessment of task-related attention may therefore provide a more accurate indication of the impact of CWMT on everyday attention regulation.

One way of assessing control of task-related attention in an everyday setting is through administering thought probes during task completion (McVay, Kane, & Kwapil, 2009; Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012). Thought probes are questions that query the focus of attention (e.g., ‘what were you thinking about right before this question appeared?’), and are administered in written form (usually by a computer) at random intervals during task completion. For each probe, participants indicate whether their thoughts were task-related, or task-unrelated. Compared to coding of behaviour, as commonly completed with children (e.g., Fisher et al., 2014), thought probes provide a more direct measurement of the focus of attention. For example, coding of behaviour may classify a child as off-task if their gaze was fixed on a distant object, which may occur when mentally performing a math calculation. Thought probes therefore provide a good measure of task-related attention for children of an age when metacognitive skills are developed (Schneider, 2008), and may indicate the effect of CWMT on attention regulation in a school setting.

Although CWMT has traditionally focused on improving academic performance, cognitive training programmes have the potential to improve cognitive skills that may protect against psychopathology (see Keshavan et al., 2014). For example, working memory and controlled attention impact the ability to engage in cognitive reappraisal, a skill which assists an individual to respond flexibility to emotional events and aids emotion regulation (Hendricks & Buchanan, 2015; Waugh & Koster, 2014). Training control of attention may therefore help a child to disengage from negative thought patterns, and refocus attention on a more adaptive topic, thus aiding regulation of negative emotion (Joormann & Tanovic, 2015; Waugh & Koster, 2014). As maintenance of goal-directed attention is also needed to execute planned behaviour, training may also impact behaviour regulation and the management of social interaction (Stegge & Terwogt, 2007). Difficulties in affect regulation and social

Author Manuscript

This article is protected by copyright. All rights reserved

perception often predate the onset of symptoms (Keshavan et al., 2014). As a result, intervening to improve management of emotion and behaviour in healthy individuals may thereby slow or prevent the onset of mental health disorders (Piet & Hougaard, 2011). Many individuals will experience their first mental health difficulties in adolescence (Lewinsohn, Clarke, Seely, & Rohde, 1994), thus exploring whether CWMT may improve emotion and behaviour regulation skills in a non-clinical sample of children may have important implications for preventative research.

There is some evidence of a positive impact of working memory training on these regulation skills in non-clinical samples. In healthy adults, working memory training improves performance on behavioural measures of emotion regulation (Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013), and reduces amygdala reactivity to aversive information (Cohen et al., 2016). Working memory training has also been demonstrated to reduce emotional vulnerability in university students at risk of developing clinical anxiety (Sari, Koster, Pourtios, & Derakshan, 2015). The impact of working memory training on emotion regulation has not yet been explored in children. In terms of behaviour regulation, previous work has established that CWMT does not improve behavioural symptoms of Attention Deficit Hyperactivity Disorder (ADHD) in children (for meta-analysis see Rapport, Orban, Kofler & Firedman, 2013). However, poor behavioural self-regulation is a premorbid predictor of later psychological difficulty (e.g., Dawes, Tarter, & Kirisci, 1997), suggesting that training behaviour regulation in those without significant symptomatology may still have a preventative effect. In a non-clinical sample, target behaviours are disruptive to learning or social interaction (e.g., rule breaking) but do not create the level of impairment experienced by those with a behavioural disorder. In a small, normative sample (N = 15), Roughan and Hadwin (2011) demonstrated that CWMT improved teacher-reported behaviour difficulties relative to a no-intervention control group. Controlled assessment of this effect with a larger sample will offer firmer conclusions on whether CWMT may impact behaviour regulation in non-clinical samples. We therefore examined the impact of CWMT on everyday challenges to emotional, behavioural, and social regulation to explore whether training may offer a potential avenue for reducing risk of future symptomatology.

In sum, this study sought to determine the effect of CWMT on task-related attention during academic tasks, and subsequently, academic performance. We hypothesised that the number of task-unrelated thoughts during task completion would mediate the impact of training on the individual's academic performance at post-training and three month follow-up, such that a larger decrease in the number of task-unrelated thoughts would lead to greater

This article is protected by copyright. All rights reserved

Author Manuscript

improvement in academic performance. We also explored whether CWMT improved regulation of social, emotional, and behavioural challenges. We hypothesised that students who completed active CWMT would experience fewer teacher-reported social, emotional, and behavioural difficulties at post-training and three month follow-up, relative to those who completed non-adaptive (placebo) training, or no training.

Method

Participants

A one-tailed power calculation estimating the previously observed mean effect of school-based training (d = .60; Holmes & Gathercole, 2014) on academic performance (i.e., reading, mathematics) in a controlled study with primary school children indicated that 36 participants were needed per condition. To allow for the average 10% attrition in Cogmed trials (Melby-Lervåg & Hulme, 2013), we aimed to recruit 40 participants in each condition.

The two participating primary schools were in the metropolitan area of Adelaide, South Australia. Invitations to participate were sent to 163 students, of whom 148 (80 females) provided informed consent. Mean age of participants was 12.25 years (*SD* = 6.66 months, range = 10.58 years – 13.50 years). As training was completed in class, cluster-randomisation was required. A computer-generated random number table was used to allocate each class of students to condition (Active training, Placebo/Non-adaptive training, Passive Control). The participation diagram is presented in Figure 1. No exclusion criteria were implemented to maximize the generalisablity of our findings to all school children. Ethnicity of the sample was 88.6% Caucasian, 8% Asian, and 3.4% Middle Eastern. There was no significant difference between conditions in ethnicity, χ^2 (8) = 9.22, p = .32, age, χ^2 (58) = 74.91, p = .07, or gender, χ^2 (2) = 4.07, p = .13. Three students experienced auditory processing disorder, one experienced high functioning autism spectrum disorder, and four experienced hearing impairments. Random allocation saw that these students were randomized between conditions.

[Figure 1]

CWMT

Active. We used the RM version of Cogmed Working Memory Training (Cogmed, 2014). Training involved completing a series of interactive, verbal and visual-spatial computer tasks that require the maintenance and reordering of information. For example, one task requires the child to remember the order in which boxes are lit, and repeat the sequence by selecting

Author Manuscript

This article is protected by copyright. All rights reserved

the appropriate boxes. The programme scaffolded the difficulty of trials to the child's ongoing performance. For full details see www.cogmed.com/rm. Participants completed the training for 45 minutes every school day for five weeks, supervised by a teacher. We attempted to train four teachers in the Coach training provided by Cogmed (which teaches the individual how to manage the technical aspects of the computerised training programme), however, two teachers stated the training was too difficult and did not complete the programme. All teachers consequently supervised the training sessions, and the first author oversaw the technical administration of training.

Non-adaptive. An unscaffolded version of Cogmed training was used as a placebo. Training was also completed on a daily basis for five weeks, however, the trials were non-adaptive. That is, the difficulty of the training tasks did not increase. Training time is consistently lower in non-adaptive relative to adaptive training (Chacko et al., 2013). To approximate non-specific treatment effects between conditions, we increased the number of trials in each training session (and thereby training time) for the Non-adaptive condition.

Outcome measures

Reading comprehension. The Progressive Achievement Test in Reading (PAT-R; ACER, 2013) is a standardised assessment of reading achievement. In a forty-minute period, participants read seven short articles and completed a multiple-choice test on the content of the articles. The number of correct items was used in all analyses. This measure possess test-retest reliability (ACER, 2013) and is used to index reading achievement in Australian schools, thereby increasing our external validity. Internal consistency in our sample was adequate ($\alpha = .86$).

Mathematical ability. The mathematics version of The Progressive Achievement Test (PAT-M; ACER, 2013) consists of 40 questions on numbers, algebra, geometry, measurement, statistics, and probability. Participants were required to select the correct answer from 5 multiple-choice options. The number of correct items was used in analyses. The measure demonstrates good predictive validity for academic grades (Fogarty, 2007), and internal consistency was adequate in our sample ($\alpha = .86$).

Task-related attention. We randomly administered ten computerised thought probes, at a rate of one every 1-4 minutes, during the reading comprehension and mathematics tasks. This procedure was taken from previous examinations of task-related attention (e.g., McVay & Kane, 2011). A tone signaled each thought probe, and the computer screen read 'please

This article is protected by copyright. All rights reserved

Author Manuscript

click what you were thinking about just before you heard the beep'. Participants indicated a) I was doing the task, b) I was thinking about other ways to do the task, c) I was thinking about other stuff I've learnt that's related to the task, d) I was thinking about a memory, e) I was thinking about the future, f) I was thinking about something else that's not on this list. Explicit instructions were given to report on the thought experienced directly before the probe, not all thoughts experienced since the last probe. Participants were also directly instructed that they needed to be honest, and that it did not matter if they were not thinking about the task. Responses a) and b) were coded as task-related, and c), d), e) and f) responses were coded as unrelated to the task. Internal consistency was adequate for responses during reading (α = .79) and mathematics (α = .78). Number of task-unrelated thoughts was used in analysis.

Social, emotional and behavioural difficulties. The Child Behavior Checklist (CBCL) is a valid and reliable assessment of children's emotional problems, behavioural problems, and social competencies (Achenbach & Rescorla, 2001). We used this measure as we were interested in everyday regulation of such challenges, rather than clinical levels of psychological symptoms. The checklist is comprised of two subscales; internalizing problems (anxiety, withdrawn/depression, somatic complaints, thought problems, and inattention) and externalizing problems (aggressive behaviour, rule breaking, and social problems). Convergent validity exists with psychological symptom measures (Nakamura, Ebesutani, Bernstein, & Chorpita, 2009). Both parent- and teacher-report versions of the checklist were administered pre-training, post-training and at three month follow-up. Due to poor return rates from parents (59% failed to return the CBCL at post-training, and 63% at follow-up), only teacher-report CBCL data were analysed. Normed scores were used in analysis.

Working memory. We administered a verbal working memory measure that utilised both storage and processing components. The Working Memory Index (WMI) of the Wechsler Intelligence Scale for Children, 4th edition (WISC-IV; Wechsler, 2003) includes Digit Span (Forwards and Backwards) and Letter Number Sequencing subtests. Both subtests have adequate test-retest reliability (r = .83 for each subtest; Wechsler, 2003). Internal consistency was adequate for this sample (α = .74). Pre-training scores were in the Average range for all conditions (Passive Control M = 92.78, SD = 11.33; Non-adaptive M = 93.11, SD = 8.59; Active M = 90.50, SD = 12.29).

This article is protected by copyright. All rights reserved

Author Manuscript

Attention measures. Three subtests of the Test of Everyday Attention for Children (TEA-CH; Manly, Robertson, Anderson, & Nimmo-Smith, 1999) assessed the child's capacity to control attention. The TEA-CH possesses adequate psychometric properties and norms for Australian students (Manly et al., 1999). We assessed both sustained and selective attention to provide a global indication of attention capacity. Sustained attention was assessed using the Score and Score DT subtests. The Score subtest involves ten trials in which participants are required to count between 9 and 15 audio tones. The length of silence between tones is variable. At the end of each trial, participants must report the number of sounds they counted. Scaled score for number of correct trials was used in analysis. The Score DT subtest adds distracting stimuli to the trials. A news report plays continuously throughout the trial, and participants are required to both count the tones and report the animal mentioned in the report. One point each is given for the correct naming of animal and number of tones. The Map Mission subtest measures selective attention. Participants were required to search a map for one minute, and circle symbols that represent a restaurant. Distractor-symbols are interspersed with 80 target symbols. The scaled score for number of identified targets was used in analysis.

Procedure

The authors have no conflict of interest to declare. This trial received ethics approval and was registered with the Australian New Zealand Clinical Trials Registry (ACTRN12614000852651[1]). Head teachers of three primary schools were approached, two of which consented to participate. Three teachers at each school gave consent to incorporate CWMT into the class schedule. Once teachers had given consent, their class was cluster-randomised to condition. This was completed within-school to ensure that both schools had one class in each condition. A parent provided informed consent and students gave assent, then training allocation was revealed. Teachers, parents, and participants were blind to whether the participant completed active or non-adaptive training, but we were unable to conceal condition for the Passive Control group.

Assessors administering and scoring the cognitive and academic measures were blind to condition. Pre-training assessments involved two group sessions at the school. In one session, students completed the reading comprehension (with thought probes) and Score and

[1] Please note that data collection had begun when the record became available online. The working memory and attention measures were also not listed on the registered protocol, as they were not primary or secondary outcomes of interest.

This article is protected by copyright. All rights reserved

Author Manuscript

Score DT tasks. In the other, the mathematics task (with thought probes), and Map Mission were completed. Sessions were counterbalanced between participants. Participants also completed the WMI in a one-to-one session, and class teachers completed the CBCL. Five weeks of training was subsequently completed. The Control condition continued with their regular school schedule for this period. Post-training assessments (i.e., the two group sessions, one individual session and CBCLs) were conducted within one week of training completion. Follow-up sessions (all measures) were completed three months after the completion of training (school continued in this time). No adverse effects or harms were reported.

Results

Data analysis approach

We completed intent-to-treat analysis using linear mixed-effects models created with the lme4 package (Bates, Maechler, Bolker, & Walker, 2013) in R (R Development Core Team, 2011). For individual predictors we present *b* coefficients (and standard error; *SEb*), the significance of which is determined by the associated 95% confidence interval. As in regression, a reference group was used for multi-level predictors; for the effect of time, we used pre-training, and when examining the difference between conditions, we used Passive Control. When making comparisons in this way, a negative *b* value indicates an effect in favour of the reference group. The initial model included a random effect of school. The first step added main effects of condition and time, and the final step added the interaction. Non significant interactions were further investigated by calculating the Bayes factor in favour of the null hypothesis, which presents evidence for no difference between conditions in change from pre-training to follow-up (with school as a random effect). Model statistics and Bayes factors for analysis of our hypotheses are presented in Table 2.

Training characteristics

Mean performance on the academic achievement tests was in the Average range (ACER, 2013) for each condition at all three assessment points (see Table 1 for descriptive statistics for outcome measures). Participants were classified as completers if they finished 20 training days. Moderate compliance was achieved, with 70.4% (n = 38) of the Active condition and 60% (n = 27) of the Non-adaptive condition completing training. Training gains on the Cogmed Improvement Index were comparable to the average training improvement (of 24; Holmes & Gathercole, 2014), and did not significantly differ between children who did (M = 30.32, SD = 26.97) and did not (M = 23.38, SD = 16.37) complete

This article is protected by copyright. All rights reserved

Author Manuscript

training, $t(52) = -0.96$, $p = .34$. Training time was significantly lower in the Non-adaptive ($M = 30.54$ minutes, $SD = 5.04$) compared to Active condition ($M = 37.11$ minutes, $SD = 9.55$), $t(84.95) = -4.42$, $p < .001$, despite increasing the trials in the Non-adaptive condition. However, both means were within the desired 30-45 minutes of daily training (Cogmed, 2016).

[Table 1]

[Table 2]

Task-related attention

Using the above steps, we first created a model predicting the total number of task-unrelated thoughts during both mathematics and reading comprehension tasks, $\chi^2(4) = 31.40$, $p < .001$, random effect $SD = 0.92$. A main effect of time was observed, such that all conditions experienced a decrease in the number of task-unrelated thoughts from pre-training to follow-up, $b = -2.17$, $SEb = 0.58$, [-3.33, -1.01], although post-training did not differ from pre-training, $b = -0.95$, $SEb = 0.58$, [-2.09, 0.24]. A main effect of condition was also evident, such that the Passive Control condition was significantly different from the Active condition, $b = -1.42$, $SEb = 0.58$, [-2.59, -0.34], but not the Non-adaptive condition, $b = 1.19$, $SEb = 0.61$, [-0.05, 2.37]. Active and Non-adaptive conditions also differed, $b = 2.61$, $SEb = 0.58$, [1.45, 3.75]. Adding the interaction between condition and time resulted in a non-significant model. The Bayes factor in favour of the null hypothesis indicated strong evidence for the absence of an interaction.

Academic performance

We next created a model predicting performance on the reading comprehension task, $\chi^2(4) = 34.48$, $p < .001$, random effect $SD = 0.01$. Although there was no significant improvement at post-training, $b = 1.96$, $SEb = 1.40$, [-0.80, 4.55], all conditions experienced significant improvement in performance from pre-training to follow-up, $b = 2.95$, $SEb = 1.40$, [0.17, 5.58]. We also observed a main effect of condition. Reading comprehension was significantly different between the Passive Control and Active conditions, $b = -3.78$, $SEb = 1.39$, [-6.45, -1.13]. The Non-adaptive condition did not significantly differ from Passive Control, $b = -1.85$, $SEb = 1.47$, [-4.79, 0.88], or Active conditions, $b = 1.93$, $SEb = 1.40$, [-0.86, 4.80].The addition of the interaction term was non-significant, with the Bayes factor indicting strong evidence for the null hypothesis.

The next model predicted mathematics performance, $\chi^2(4) = 22.49$, $p < .001$, random effect $SD = 3.01$. A main effect of time indicated that all conditions experienced significant improvement from pre- to post-training, $b = 2.94$, $SEb = 1.29$, [0.42, 5.49], but that this

This article is protected by copyright. All rights reserved

improvement was not sustained at follow-up, *b* = 1.79, *SEb* = 1.29, [-0.70, 4.24]. We also observed a significant main effect of condition, such that performance was significantly different between the Passive Control and Non-adaptive conditions, *b* = -4.44, *SEb* = 1.36, [-7.17, -1.74]. The Active condition also differed from Passive Control, *b* = -3.12, *SEb* = 1.29, [-5.79, -0.54]. There was no evidence of a difference between Active and Non-adaptive conditions, *b* = -1.32, *SEb* = 1.27, [-3.81, 1.03]. No interaction was evident between condition and time. Again, the Bayes factor indicated strong evidence for the null hypothesis.

Indirect effects. We also predicted that training would indirectly improve academic performance through impacting task-related attention during task completion. When the independent variable does not uniquely predict the outcome variable, an indirect effect may be erroneously rejected by Baron and Kenny's (1986) prerequisites (Hayes, 2013; Preacher & Hayes, 2004). We therefore assessed indirect effects through task-related attention using Process (Hayes, 2012) to create 10, 000 bootstrapped samples for each analysis. No evidence was found for indirect effects on reading comprehension (at post-training, *b* = .13, *SEb* = .25, [-.16, .93]; follow-up, *b* = .13, *SEb* = 0.25, [-0.14, 1.02]) or mathematics (at post-training, *b* = .13, *SEb* = 0.24, [-0.13, 1.00]; follow-up, *b* = .26, *SEb* = 0.34, [-0.18, 1.21].

Social, emotional and behavioural issues

We next determined the effect of training on teacher-reported social, emotional, and behavioural difficulties. We created a series of models predicting normed scores on the CBCL, using the same steps as above. Despite persistence from researchers, a large number of CBCLs (37%) were not received from teachers at follow-up. Due to a disproportionate amount of missing data between conditions, we chose to only examine change in CBCL scores between pre- and post-training.

Non-significant initial models indicated no main effects of time or condition in predicting total internalizing problems (χ^2 (3) = 6.64, *p* = .08, random effect *SD* = 3.60) or externalizing problems (χ^2 (3) = 2.04, *p* = .56, random effect *SD* = 1.88). There was also no evidence for an interaction between condition and time in predicting internalizing or externalizing problems (see Table 2). Further exploration of the CBCL subscales yielded non-significant initial models, that is, no evidence for main effects of condition or time, for aggression (χ^2 (3) = 1.11, *p* = 0.77, random effect *SD* = 0.56), social problems (χ^2 (3) = 4.07, *p* = 0.25, random effect *SD* = 0.35), hyperactivity (χ^2 (3) = 3.07, *p* = 0.38, random effect *SD* = 0.63), and rule breaking behaviour (χ^2 (3) = 6.45, *p* = 0.09, random effect *SD* = 0.53). Though

This article is protected by copyright. All rights reserved

Author Manuscript

significant models were found, there were no main effects of condition or time on somatic complaints (χ^2 (3) = 9.81, *p* = 0.02, random effect *SD* = 0.03) or anxiety (χ^2 (3) = 9.06, *p* = 0.03, random effect *SD* = 0.57). There was a main effect of condition on depression, (χ^2 (3) = 10.69, *p* = 0.01, random effect *SD* = 0.29), such that the Non-adaptive condition demonstrated a lower score than the Active condition (*b* = -0.45, *SEb* = 0.16, [-0.78, -0.12]), along with an effect of condition on thought problems, such that the Non-adaptive condition demonstrated a lower score than Passive Control (*b* = -0.42, *SEb* = 0.17, [-0.79, -0.12]). No other effects were observed.

As demonstrated in Table 2, there was no evidence of interactions between condition and time in predicting any of the subscales. Bayes factors offered equivocal evidence for the null and alternate hypothesis for all factors other than aggression, anxiety, and thought problems, for which substantial evidence was found for the null hypothesis. In sum, neither the Active or Non-adaptive conditions demonstrated any significant improvement in social, emotional, or behavioural issues relative to Passive Control.

Capacity measures

We completed a final series of models to examine change in scores on psychometric assessments of working memory and attention. There was no interaction between time and condition in predicting WMI, χ^2 (4) = 6.98, *p* = .14, random effect *SD* = 0.01. We also found no evidence for training effects on the Score, χ^2 (4) = 6.59, *p* = .16, random effect *SD* = 0.02, Score DT, χ^2 (4) = 1.68, *p* = .79, random effect *SD* = 0.89, or Map Mission tasks, χ^2 (4) = 3.69, *p* = .45, random effect *SD* = 0.78. Bayes factors indicated strong evidence for the null hypothesis on attention measures (Score = 5.09, Score DT = 7.23, Map Mission = 6.42), and equivocal evidence for the null and alternate hypothesis (0.01) for working memory.

Discussion

This study explored whether school-based CWMT impacted both academic and psychological aspects of school performance. Gains were observed on the trained tasks, but not on working memory capacity (similar to previous studies that completed follow-up assessment of verbal working memory; Melby-Lervåg & Hulme, 2013), or the attention capacity measures. The Active training condition did not demonstrate any greater improvement in task-related attention, reading, mathematics, or regulation of emotional, social, and behavioural challenges relative to the Non-adaptive and Passive control conditions. Indeed, the Bayes Factors for our main outcome measures demonstrated strong

Author Manuscript

This article is protected by copyright. All rights reserved

evidence for the null hypothesis. Overall, no support was provided for a positive impact of CWMT on everyday school functioning.

We have provided the first placebo-controlled examination of whether CWMT may aid regulation of everyday social, emotional, and behavioural challenges. No evidence was found for training effects on teacher-reported capabilities. We recruited an unselected sample, in line with the progression of research on the impact of working memory training on emotion regulation in adults (e.g., Schweizer et al., 2013), and with our interest in potentially preventative effects of training regulation. Although we found no evidence for working memory training improving response to everyday social, emotional and behavioural challenges, training may yield greater improvement for those children with more significant regulation difficulties. Use of samples at-risk of psychopathology (e.g., current emotion regulation issues, or family history of psychological disturbance) and examination of sub-clinical scores on self- or parent-report psychological symptom measures therefore warrant further exploration. Our study may be limited by the fact that teachers completing emotion and behaviour ratings for the Passive Control condition were aware that the student had not completed training, although the Non-Adaptive condition does control for demand and expectancy effects. Further, we were only able to analyse one (short-term) outcome point, reflecting the difficulties in completing research on these factors in school settings. Further investigation of long-term effects is therefore needed, as it may take some time for children to apply trained skills to feelings and behaviour. In addition, although working memory training with neutral stimuli leads to improved emotion regulation in adults (Sari et al., 2015), using training materials that include emotional stimuli (as in Schweizer et al., 2013) may have a greater impact on emotion regulation skills. Other training techniques hold some promise in improving social and emotional competence (e.g., mindfulness training; Schonert-Reichl & Lawlor, 2010), however further exploration of the impact of cognitive training on these outcomes is warranted. Our findings may be used to develop more targeted examination of cognitive-based interventions for emotional, social, and behavioural regulation, and advance transdiagnotic approaches to children’s wellbeing.

The lack of training effect on task-unrelated thoughts (and also teacher ratings of inattention) indicates that CWMT will not improve task-related attention in an academic setting. This finding, in addition to null effects on psychometric attention measures which do not overlap with training tasks, suggests that any attention gains do not generalise. The relationship between working memory and the experience of task-unrelated thoughts (which is often referred to as mind wandering) is well theorised and explored in adult samples (e.g.,

Author Manuscript

This article is protected by copyright. All rights reserved

McVay & Kane, 2009), however, it has not been empirically assessed in primary school children. The absence of an effect of working memory training on task-unrelated thoughts may indicate that the relationship between working memory and mind wandering is in need of further evaluation in children. As mindfulness training has also been found to improve task-related attention (Mrazek et al., 2013), future research may also wish to focus on the impact of other interventions on task-related attention.

Finally, our findings add to growing evidence that CWMT will not improve academic performance (Melby-Lervåg & Hulme, 2013). The current study possessed a number of strengths which lend weight to these findings, and build upon the limitations of previous research. These include both active and passive control groups, adequate statistical power, multiple indicators of performance, calculation of Bayes Factors to assess evidence for the null hypothesis, and consideration of random effects due to sampling. Our findings build upon null effects in other randomised, controlled trials (e.g., Dunning, Holmes, & Gathercole, 2013) to confirm that CWMT will need to be reconsidered.

There are a number of avenues that may be pursued to move the field forward. First, one difference between our study and others that have demonstrated academic improvement is that we recruited children of a range of academic ability and cognitive capacity, rather than only those experiencing impairment (e.g., Dahlin et al., 2013; Kuhn & Holling, 2014; Holmes, Gathercole, & Dunning, 2009; Holmes & Gathercole, 2014). Although training effects on verbal and visual spatial working memory measures appear to be larger in unselected samples such as ours (relative to impaired samples; Melby-Lervåg & Hulme, 2013), this is not observed on far transfer tasks such as academic performance, and most evidence for training improvements on academic outcomes has been found in samples experiencing academic or cognitive impairment. Future research may therefore wish to identify whether there are some specific populations for whom CWMT is potentially beneficial.

Alternatively, it may be that the training tasks need to more closely reflect daily activities. Explicit training in the context of academic tasks may more directly impact everyday functioning. For example, working memory training may be embedded into mathematics activities by incrementally increasing the working memory load during the activity. Similarly, children may need explicit instruction in practical strategies that can help them transfer trained effects to daily functioning (Gathercole et al., 2012). Indeed, strategy use may underlie why gains are seen on untrained tasks that are conceptually and procedurally similar to the training tasks, but not on tasks dissimilar to training, as these tasks

This article is protected by copyright. All rights reserved

require different strategies. For example, working memory training improves grouping strategies (i.e., temporal grouping of sequences of digits or letters into groups of three; Dunning & Holmes, 2014), which may lead to improved performance on any trained or untrained task which benefits from grouping of information. Further development and refinement of working memory training programmes may produce an effect that CWMT does not.

However, findings from the current and previous randomised, controlled trials (e.g., Dunning, Holmes, & Gathercole, 2013) suggest that it is more important to consider why working memory training does not impact daily functioning. Theoretical rationale for training may need to be reconsidered (see Shipstead et al., 2012). Our findings demonstrate that CWMT will not improve working memory capacity, consistent with fixed capacity theories of working memory (see Engle, Tuholski, Laughlin, & Conway, 1999). Further, our results suggest the assumption that repeated practice using working memory will generalise and improve other cognitive skills is incorrect. As such, we encourage development of new interventions that are able to improve academic and psychological outcomes for children, as our results add to substantial evidence that CWMT will not improve school-based outcomes.

Supporting information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Consort Checklist

Acknowledgements

Funding for this research was provided by the Australian Research Council, Science of Learning Research Centre. The authors have declared that they have no competing or potential conflicts of interest.

Correspondence

Caitlin Hitchcock, MRC Cognition and Brain Sciences Unit, 15 Chaucer Road Cambridge CB2 7EF, UK; Email: Caitlin.hitchcock@mrc-cbu.cam.ac.uk

Key points

- Cogmed Working Memory Training (CWMT) may form a novel approach to optimising cognitive processes that enhance academic performance, but also has the potential to improve the regulation of emotion, social problems, and behavioural difficulties
- 148 children were cluster-randomised to active CWMT, placebo training, or no training

Author Manuscript

This article is protected by copyright. All rights reserved

- No training effects were observed on control of task-related attention, academic performance, or regulation of emotional, social or behavioural challenges
- Current working memory training programmes may need to be enhanced to impact regulation of emotional, social, or behavioural challenges for children

References

ACER. (2013). *The Progressive Achievement Tests: Mathematics*. Melbourne, Victoria: ACER Press.

ACER. (2013). *The Progressive Achievement Tests: Reading*. Melbourne, Victoria: ACER Press.

Achenbach, T. M., & Rescorla, L. (2001). *ASEBA School-Age Forms & Profiles*: Aseba.

Baddeley, A. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences, 4*, 417-423. doi:10.1016/S1364-6613(00)01538-2

Baddeley, A. D., & Hitch, G. (1974). Working memory. *The Psychology of Learning and Motivation, 8*, 47-89.

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51*, 1173-1182. doi: 10.1037/0022-3514.51.6.1173

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2013). lme4: Linear mixed-effects models using Eigen and S4. *R package version*, 1.0-4.

Chacko, A., Bedard, A. C., Marks, D. J., Feirsen, N., Uderman, J. Z., Chimiklis, A., . . . Ramon, M. (2013). A randomized clinical trial of Cogmed Working Memory Training in school-age children with ADHD: A replication in a diverse sample using a control condition. *Journal of Child Psychology and Psychiatry, 55,* 247-255. doi: 10.1111/jcpp.12146

Cogmed. (2016). How it works. Retrieved 6th May 2016, from www.cogmed.com.au

Cohen, N., Margulies, D. S., Ashkenazi, S., Schaefer, A., Taubert, M., Henik, A., . . . Okon-Singer, H. (2016). Using executive control training to suppress amygdala reactivity to aversive information. *NeuroImage, 125*, 1022-1031. doi: 10.1016/j.neuroimage.2015.10.069

Conway, A. R., Jarrold, C. E., Kane, M. J., Miyake, A., & Towse, J. N. (2007). *Variation in Working Memory*. Oxford: Oxford University Press.

Author Manuscript

This article is protected by copyright. All rights reserved

Dahlin, K. I. (2013). Working memory training and the effect on mathematical achievement in children with attention deficits and special needs. *Journal of Education and Learning*, *2*, 118-133. doi:10.5539/jel.v2n1p118

Dawes, M. A., Tarter, R. E., & Kirisci, L. (1997). Behavioral self-regulation: Correlates and 2 year follow-ups for boys at risk for substance abuse. *Drug and Alcohol Dependence, 45*, 165-176. doi: 10.1016/S0376-8716(97)01359-8

Dunning, D., & Holmes, J. (2014). Does working memory training promote the use of strategies on untrained working memory tasks? *Memory & Cognition, 42,*854-862. doi: 10.3758/s13421-014-0410-5

Dunning, D., Holmes, J., & Gathercole, S. E. (2013). Does working memory training lead to generalized improvements in children with low working memory? A randomized controlled trial. *Developmental Science, 16*, 915-925. doi: 10.1111/desc.12068doi: 10.3758/s13421-014-0410-5

Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. A. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology: General, 128*, 309-331. doi:10.1037/0096-3445.128.3.309

Fisher, A. V., Godwin, K. E., & Seltman, H. (2014). Visual environment, attention allocation, and learning in young children: When too much of a good thing may be bad. *Psychological Science*, *27,* 1362-1370. doi: 10.1177/0956797614533801

Fogarty, G. (2007). Research on the Progressive Achievement Tests and academic achievement in secondary schools. Australia: Australian Council for Educational Research.

Gathercole, S. E., & Alloway, T. P. (2008). *Working memory and learning: A practical guide for teachers.* London: Sage.

Gathercole, S. E., Dunning, D. L., & Holmes, J. (2012). Cogmed training: Let's be realistic about intervention research. *Journal of Applied Research in Memory and Cognition, 1*, 201-203. doi: http://dx.doi.org/10.1016/j.jarmac.2012.07.007

Gibson, B. S., Gondoli, D. M., Johnson, A. C., Steeger, C. M., & Morrissey, R. A. (2012). The future promise of Cogmed working memory training. *Journal of Applied Research in Memory and Cognition, 1*, 214-216. doi: 10.1016/j.jarmac.2012.07.003

Gray, S. A., Chaban, R., Martinussen, R., Goldberg, H., Gotlieb, R., Kronitz, R., . . . Tannock, R. (2012). Effects of a computerized working memory training program on working memory, attention, and academics in adolescents with severe LD and

This article is protected by copyright. All rights reserved

Author Manuscript

comorbid ADHD: A randomized clinical trial. *Journal of Child Psychology and Psychiatry, 53*, 1277–1284. doi: 10.1111/j.1469-7610.2012.02592.x

Green, C., Long, D., Green, D., Iosif, A.-M., Dixon, J. F., Miller, M., . . . Schweitzer, J. (2012). Will working memory training generalize to improve off-task behavior in children with Attention-Deficit/Hyperactivity Disorder? *Neurotherapeutics, 9*, 639-648. doi: 10.1007/s13311-012-0124-y

Hayes, A. F. (2012). PROCESS: A versatile computational tool for observed variable mediation, moderation, and conditional process modeling. Retrieved December 2014 from http://www.afhayes.com/public/process2012.pdf

Hayes, A. F. (2013). *Introduction to Mediation, Moderation, and Conditional Process Analysis: A regression-based approach*. New York: Guilford Press.

Hendricks, M. A., & Buchanan, T. W. (2015). Individual differences in cognitive control processes and their relationship to emotion regulation. *Cognition and Emotion*, 1-13. doi:10.1080/02699931.2015.1032893

Holmes, J., & Gathercole, S. E. (2014). Taking working memory training from the laboratory into schools. *Educational Psychology, 34*, 440-450. doi: 10.1080/01443410.2013.797338

Holmes, J., Gathercole, S. E., & Dunning, D. L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science, 12*, F9-F15. doi: 10.1111/j.1467-7687.2009.00848.x

Joormann, J., & Tanovic, E. (2015). Cognitive vulnerability to depression: examining cognitive control and emotion regulation. *Current Opinion in Psychology, 4*, 86-92. doi: 10.1016/j.copsyc.2014.12.006

Kane, M. J., Bleckley, M. K., Conway, A. R., & Engle, R. W. (2001). A controlled-attention view of working-memory capacity. *Journal of Experimental Psychology: General, 130*, 169-183. doi: 10.1037/0096-3445.130.2.169

Kane, M. J., Brown, L. H., McVay, J. C., Silvia, P. J., Myin-Germeys, I., & Kwapil, T. R. (2007). For whom the mind wanders, and when: An experience-sampling study of working memory and executive control in daily life. *Psychological Science, 18*, 614-621. doi:10.1111/j.1467-9280.2007.01948.x

Keshavan, M. S., Vinogradov, S., Rumsey, J., Sherrill, J., & Wagner, A. (2014). Cognitive training in mental disorders: Update and future directions. *The American Journal of Psychiatry, 171*, 510-522. doi:10.1176/appi.ajp.2013.13081075

Author Manuscript

This article is protected by copyright. All rights reserved

Kuhn, J.-T., & Holling, H. (2014). Number sense or working memory? The effect of two computer-based trainings on mathematical skills in elementary school. *Advances in Cognitive Psychology, 10*, 59-67. doi: 10.5709/acp-0157-2

Lewinsohn, P. M., Clarke, G. N., Seeley, J. R., & Rohde, P. (1994). Major depression in community adolescents: Age at onset, episode duration, and time to recurrence. *Journal of the American Academy of Child & Adolescent Psychiatry, 33*, 809-818. doi: 10.1097/00004583-199407000-00006

Lui, M., & Tannock, R. (2007). Working memory and inattentive behaviour in a community sample of children. *Behavioral and Brain Functions, 3*, 1-11. doi:10.1186/1744-9081-3-12

Manly, T., Robertson, I. H., Anderson, V., & Nimmo-Smith, I. (1999). *TEA-Ch: The test of everyday attention for children*: Thames Valley Test Company Bury St. Edmunds, England.

McVay, J. C., & Kane, M. J. (2012). Why does working memory capacity predict variation in reading comprehension? On the influence of mind wandering and executive attention. *Journal of Experimental Psychology: General, 141*, 302-320. doi:10.1037/a0025250

McVay, J. C., Kane, M. J., & Kwapil, T. R. (2009). Tracking the train of thought from the laboratory into everyday life: an experience-sampling study of mind wandering across controlled and ecological contexts. *Psychonomic Bulletin & Review, 16*, 857-863. doi: 10.3758/PBR.16.5.857

Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology, 49*, 270-291. doi: 10.1037/a0028228

Nakamura, B., Ebesutani, C., Bernstein, A., & Chorpita, B. (2009). A Psychometric analysis of the Child Behavior Checklist DSM-Oriented scales. *Journal of Psychopathology and Behavioral Assessment, 31*, 178-189. doi: 10.1007/s10862-008-9119-8

Piet, J., & Hougaard, E. (2011). The effect of mindfulness-based cognitive therapy for prevention of relapse in recurrent major depressive disorder: A systematic review and meta-analysis. *Clinical Psychology Review, 31*, 1032-1040. doi: 10.1016/j.cpr.2011.05.002

Preacher, K., & Hayes, A. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods, Instruments, & Computers, 36*, 717-731. doi: 10.3758/BF03206553

R Development Core Team. (2011). *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing.

This article is protected by copyright. All rights reserved

Author Manuscript

Rapport, M. D., Orban, S. A., Kofler, M. J., & Friedman, L. M. (2013). Do programs designed to train working memory, other executive functions, and attention benefit children with ADHD? A meta-analytic review of cognitive, academic, and behavioral outcomes. *Clinical Psychology Review, 33*, 1237-1252. doi: 10.1016/j.cpr.2013.08.005

Risko, E. F., Anderson, N., Sarwal, A., Engelhardt, M., & Kingstone, A. (2012). Everyday attention: Variation in mind wandering and memory in a lecture. *Applied Cognitive Psychology, 26*, 234-242. doi: 10.1002/acp.1814

Roughan, L., & Hadwin, J. A. (2011). The impact of working memory training in young people with social, emotional and behavioural difficulties. *Learning and Individual Differences, 21*, 759-764. doi: 10.1016/j.lindif.2011.07.011

Sari, B. A., Koster, E. H. W., Pourtois, G., & Derakshan, N. (2015). Training working memory to improve attentional control in anxiety: A proof-of-principle study using behavioral and electrophysiological measures. *Biological Psychology*. doi: 10.1016/j.biopsycho.2015.09.008

Schneider, W. (2008). The development of metacognitive knowledge in children and adolescents: Major trends and implications for education. *Mind, Brain, and Education, 2*, 114-121. doi: 10.1111/j.1751-228X.2008.00041.x

Schonert-Reichl, K., & Lawlor, M. (2010). The effects of a mindfulness-based education program on pre- and early adolescents' well-being and social and emotional competence. *Mindfulness, 1*, 137-151. doi: 10.1007/s12671-010-0011-8

Schweizer, S., Grahn, J., Hampshire, A., Mobbs, D., & Dalgleish, T. (2013). Training the emotional brain: Improving affective control through emotional working memory training. *The Journal of Neuroscience, 33*, 5301-5311. doi: 10.1523/JNEUROSCI.2593-12.2013

Shipstead, Z., Hicks, K. L., & Engle, R. W. (2012). Cogmed working memory training: Does the evidence support the claims? *Journal of Applied Research in Memory and Cognition, 1*, 185-193. doi: 10.1016/j.jarmac.2012.06.003

Söderqvist, S. & Nutley, S. (2016). Cogmed Working Memory Training Claims & Evidence – Extended Version V.4. Retrieved from www.cogmed.com/wp-content/uploads/CogmedClaimsEvidence.pdf

Stegge, H., & Terwogt, M. M. (2007). Awareness and regulation of emotion in typical and atypical development. In J. J. Gross (Ed.), *Handbook of Emotion Regulation* (pp. 269-286). New York: Guilford Press.

This article is protected by copyright. All rights reserved

Author Manuscript

Thorell, L. B., Lindqvist, S., Bergman Nutley, S., Bohlin, G., & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental Science, 12*, 106-113. doi:10.1111/j.1467-7687.2008.00745.x

Unsworth, N., & McMillan, B. D. (2013). Mind wandering and reading comprehension: Examining the roles of working memory capacity, interest, motivation, and topic experience. *Journal of Experimental Psychology: Learning, Memory and Cognition, 39*. doi: 10.1037/a0029669

Unsworth, N., & Spillers, G. J. (2010). Working memory capacity: Attention control, secondary memory, or both? A direct test of the dual-component model. *Journal of Memory and Language, 62*, 392-406. doi:10.1016/j.jml.2010.02.001

Waugh, C. E., & Koster, E. H. W. (2015). A resilience framework for promoting stable remission from depression. *Clinical Psychology Review, 41*, 49-60. doi: 10.1016/j.cpr.2014.05.004

Wechsler, D. (2003). *Wechsler Intelligence Scale for Children- Fourth Edition (WISC-IV) Administration and Scoring Manual*. San Antonio, TX: The Psychological Corporation.

Author Manuscript

This article is protected by copyright. All rights reserved

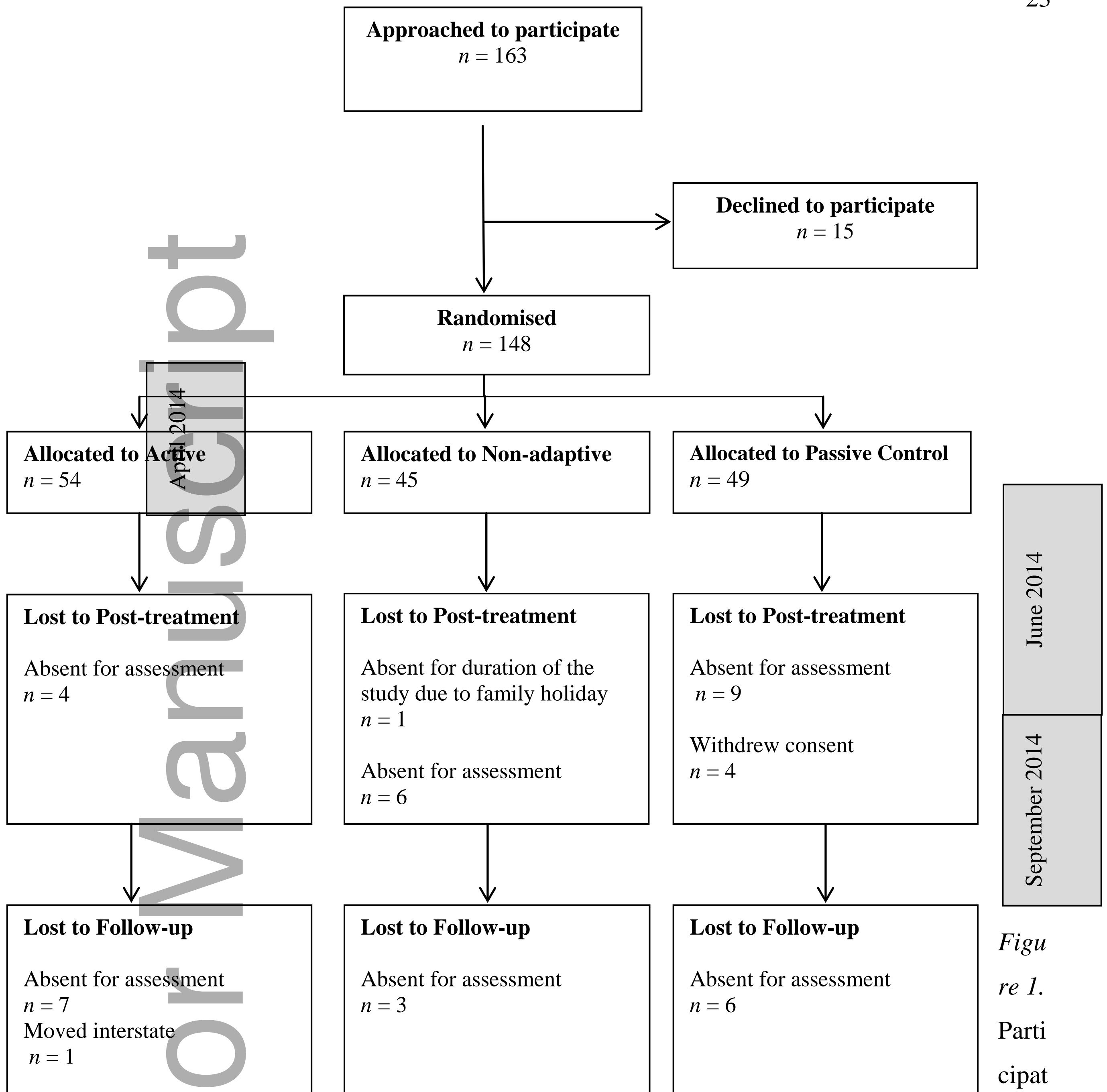

Figure 1. Participation diagram for all approached participants. Mixed-effects modelling allowed us to include the previously collected data from participants who were lost to attrition, or were absent for an assessment (by treating missing data as missing at random). Data were therefore analysed for 54 active, 44 non-adaptive, and 45 passive control participants.

Author Manuscript

This article is protected by copyright. All rights reserved

Author Manuscript

This article is protected by copyright. All rights reserved

Table 1

	Passive Control			Non-adaptive			Active		
	Pre	Post	Follow up	Pre	Post	Follow up	Pre	Post	Follow up
Reading	128.48 (12.05)	132.03 (12.48)	133.57 (11.49)	128.23 (10.46)	129.99 (10.50)	130.06 (11.40)	126.58 (10.76)	127.27 (11.18)	128.60 (11.90)
Mathematics	127.56 (9.87)	129.76 (12.57)	129.29 (11.13)	121.97 (8.65)*	127.23 (10.83)	124.62 (10.58)	125.02 (11.49)	126.61 (9.50)	126.44 (10.53)
TUT- Read	3.40 (2.74)	2.68 (2.56)	1.61 (1.94)	3.30 (2.49)	2.59 (2.73)	2.57 (2.28)	2.02 (2.44)*	2.25 (2.80)	1.26 (2.26)
TUT-Math	2.95 (2.75)	3.26 (2.78)	3.31 (2.80)	4.51 (2.57)*	2.47 (2.56)	3.50 (2.91)	2.78 (2.50)	2.46 (2.70)	1.74 (2.65)
Internal	43.35 (8.02)	41.86 (5.85)	41.93 (6.20)	42.33 (6.92)	42.26 (5.55)	41.57 (5.21)	44.98 (8.52)	41.74 (5.23)	39.54 (2.84)
External	44.30 (6.37)	45.40 (6.68)	44.40 (5.77)	45.57 (5.85)	44.41 (5.09)	43.87 (3.62)	46.48 (7.70)	45.11 (5.72)	42.46 (0.51)

Mean (Standard Deviation) Performance on Outcome Measures by Condition at Pre-training, Post-training and Three Month Follow-up

Note. TUT-Read = number of task-unrelated thoughts during the reading comprehension task; TUT-Math = number of task-unrelated thoughts during the mathematics task; Internal = internalising problems indexed by the Child Behaviour Checklist (CBCL; Achenbach & Rescorla, 2001). External= Externalising problems indexed by the CBCL

* value significantly different from the Passive Control condition at $p < .05$

This article is protected by copyright. All rights reserved

Author Manuscript

Table 2

Model Statistics for Hypothesised Interactions between Condition and Time.

Outcome	Chi Square	Random effect SD	Bayes factor
Task-related attention	χ^2 (4) = 2.67, p = .61	0.93	9.84
Reading comprehension	χ^2 (4) = 1.40, p = .84	0.01	5.87
Mathematics	χ^2 (4) = 1.62, p = .80	3.02	10.81
Total internalising problems	χ^2 (2) = 2.99, p = .22	3.60	0.24
Thought problems	χ^2 (2) = 2.67, p = .26	0.18	3.20
Anxiety	χ^2 (2) = 0.98, p = .61	0.57	5.63
Depression	χ^2 (2) = 5.22, p = .07	0.29	0.43
Somatic complaints	χ^2 (2) = 2.84, p = .24	0.03	3.80
Total externalising problems	χ^2 (2) = 2.63, p = .27	1.88	2.00
Inattention	χ^2 (2) = 3.78, p = .15	0.90	0.21
Aggression	χ^2 (2) = 0.74, p = .69	0.56	7.12
Rule breaking behaviour	χ^2 (2) = 1.61, p = .45	0.53	2.21
Hyperactivity	χ^2 (2) = 0.28, p = .87	0.63	0.15
Social difficulties	χ^2 (2) = 1.56, p = .46	0.35	1.60

Note. Random effect SD = standard deviation for the random effect of school; Bayes factor is in favour of the null hypothesis (i.e., evidence for no difference between conditions in change from pre-training to follow-up).

Author Manuscript

This article is protected by copyright. All rights reserved