Memory Mates: An evaluation of a classroom-based, student-focused working memory intervention

Abstract

This applied experimental research tested the effectiveness of a universal, student-focused intervention ("Memory Mates"), specifically focussed on supporting students to use attention and working memory strategies within academic contexts, unlike computer-based programs. Memory Mates is presented in the form of icons and explanations, with the strategies embedded within the classroom. Analyses compared the impact of the intervention over eight months in three schools with three control schools, comprising thirteen Year 4 primary school classes. The intervention group students showed a significant improvement in mathematics and spelling; however, there was no differential effect on reading comprehension or academic engagement. Based on the present results, it is contended that implementing Memory Mates within classroom contexts demonstrated promising potential as a new approach to supporting academic progress.

Introduction

The importance of working memory for academic performance and classroom learning has been increasingly recognised within psychological and educational research. Working memory is particularly integral to successful classroom functioning from kindergarten through to secondary school, in areas such as following instructions, general reasoning, verbal comprehension and undertaking multi-step mathematical tasks (Alloway & Copello, 2013). Children's working memory capacity typically increases with age (Dehn, 2008; Roberts et al., 2015); however, it is likely that specific intervention programs can enhance the development of students' working memory capacity and use of working memory strategies (Davis, Sheldon, & Colmar, 2014).

Working memory is defined as the capacity to temporarily hold and manipulate information (Baddeley, 2000), and it is a limited capacity that can be overloaded by excessive storage or processing demands at school (Alloway, 2006). More specifically, 'working memory consists of several interacting subsystems that include specialised stores for verbal and visuo-spatial material, and an attentional component that controls activity within working memory' (Gathercole, 2008, p. 382).

Working memory has been linked to a number of specific academic skills including mathematics (Bull & Scerif, 2001) reading comprehension (Normand & Tannock, 2014), and spelling achievement (Re, Mirandola, Esposito, & Capodieci, 2014). Working memory is not only crucial to the acquisition of new information, but it is also predictive of and correlated with academic achievement (Colmar, 2016; Pickering, 2006). Monette, Bigras, and Guay (2011) found that working memory measured at the beginning of school predicted maths, reading and writing achievement at the end of first grade, with working memory still predictive of maths achievement after pre-existing differences in pre-academic abilities and socio-economic differences were controlled for. Further, recent research (Colmar, 2013, 2016) found strong, significant correlations between working memory, academic achievement and academic engagement.

Given the importance of working memory to academic outcomes, and the problems for individual students experiencing working memory difficulties, the potential of interventions that aim to improve working memory functioning has become a key applied research focus (e.gs, Alloway, 2011; Dehn, 2008; Elliott, Gathercole, Alloway, Holmes, & Kirkwood, 2010; Gathercole & Alloway, 2007, 2008). From an extensive analysis of the literature, we propose that there are three main ways cited to increase working memory capacity and skills and reduce working memory overload.

1. Firstly, working memory can be trained directly, typically through individual computer-based training, noting the limitations, particularly in transfer of training in this approach (Colmar & Double, 2017; Roberts et al., 2016).

2. Secondly, the way information and learning are presented in the context of the classroom learning environment, primarily through the agency of the teacher, can be managed and adapted. This within-classroom management can be achieved by providing knowledge and skills' training to improve a teacher's understanding of and ability to provide adjustments for students with working memory issues.

3. Thirdly, students can be provided with strategies to self-manage and to increase their frequency of independently using their existing attention and working memory strategies. In addition, a student-oriented program would also aim to extend the range of attention and

working memory strategies the students can access within the classroom context, and potentially also to increase their working memory capacity.

In addressing the third approach, which has not been previously researched, a within-classroom program has been developed (Colmar, Davis, & Sheldon, 2016; Davis et al., 2014), consisting of a set of ten named icons with a written explanation, called Memory Mates. Students are taught and supported in using the ten key strategies focused on how to best attend, learn and engage in classroom activities across all academic areas. Children are also encouraged to be self-reflective, with initial evidence suggesting that this leads to meta-cognitive awareness of their own learning processes, and generalisation of attention and working memory strategies learned at school. The strategies are presented as student-relevant icons with short explanations (see Figure 1, Method). For a detailed explanation of the strategies and resources that comprise the Memory Mates program see Sheldon, Davis, and Colmar (2015). Importantly, the classroom teacher is of key importance in ensuring the availability of materials, and in providing students with support and reminders about using their Memory Mates.

The present paper reports the findings from a successful, large-scale evaluation of the Memory Mates program within the context of existing research on attention and working memory, particularly work linked to interventions with primary-aged students. The Memory Mates program is a set of strategies for students that offers a focus on teaching and supporting attention, working memory and academic learning embedded in functionally relevant classroom contexts to enhance the learning process, that is, “how” to learn. However, based on existing evidence about the links between working memory and academic achievement

(Monette et al., 2011; Pickering, 2006), it is predicted that students' academic skills will improve, which is the "what" of learning.

Literature Review

Research has estimated that 10 to 15% of all children experience significant working memory difficulties (Elliott et al., 2010). Further, low working memory is a high-risk factor for educational underachievement (Alloway, Gathercole, Kirkwood, & Elliott, 2009). Children with working memory difficulties often struggle in the classroom setting because they can become overloaded with and fail to retain instructions and information needed to complete a task (Elliott et al.). The demands of individual learning episodes can be too challenging and cognitively effortful for such students; therefore, they fail to acquire critical knowledge and skills necessary to engage with learning tasks, and thus they fail to make the same rate of progress in learning and academic achievement as their peers (Alloway, 2009; Gathercole & Alloway, 2007). Further, individual differences in performance on working memory tasks exist, particularly across ages (Gathercole & Alloway, 2007, 2008), but with high degrees of variability in terms of upper, lower and mean levels of capacity within specific age levels (Alloway, 2006; Gathercole, Lamont, & Alloway, 2006).

Alloway and Alloway (2010) clarified that working memory is separate from intelligence as measured, with a large meta-analysis (Ackerman, Beier, & Boyle, 2005) noting that working memory is a specific, independent cognitive structure and one that predicts future learning, alongside academic knowledge. In contrast, intelligence was found to make only a small contribution to the variance in future learning outcomes (Alloway, 2009). Alloway and Alloway (2010) demonstrated that working memory in children beginning school was a better predictor than intelligence of literacy and numeracy achievement six years later.

Conjecture remains over whether working memory interventions result in an increase in working memory capacity, or if interventions lead to improvements in a student's effectiveness at using their working memory capacity. Better use of capacity is evidenced by students' use of newly taught strategies and skills and also by their more frequent use of existing strategies, in part by being reminded of them and encouraged to use them, particularly by their teachers and peers (Davis et al., 2014; Tidwell, Dougherty, Chrabaszcz, Thomas, & Mendoza, 2014). Further, it is possible that the capacity and strategy use are closely linked, perhaps with greater successful strategy use leading to increased capacity; however, there is no research confirming this prediction. While this distinction is of theoretical importance, it may be less important for practical educational purposes; instead, the criteria for success in these instances are whether a working memory intervention results in measurable gains in student academic engagement and academic achievement. For example, in discussing his small-scale study implemented in a primary school, but not within a classroom, Witt (2011) suggested that the significant improvements he observed in some working memory tasks and in a mathematical addition task may have been attributable to improved working memory strategies rather than capacity increase.

To date most popular working memory interventions have involved computerised training programs external to the classroom, for example CogMed (Klingberg et al., 2005) and Jungle Memory (Alloway & Alloway, 2013). Klingberg (2010) argued that working memory capacity can be increased over and above the typical developmental changes in working memory capacity observed with age. Reviews of the efficacy of such programs have presented mixed results, with some reviews providing optimistic support for the benefits of computerised cognitive training (e.g. Morrison & Chein, 2011). However, other reviewers have come to more sceptical conclusions (e.gs, Redick, Shipstead, Wiemers, Melby-Lervåg, & Hulme, 2015; Shipstead, Redick, & Engle, 2012), particularly concerning the issue of generalisation or transfer gains to non-related learning tasks (Rode, Robson, Purviance, Geary, & Mayr, 2014) and whether gains are maintained over time (Apter, 2012; Hulme & Melby-Lervåg, 2012). The evidence that computerised working memory training can lead to transferable benefits to academic performance is particularly scarce, with little evidence that gains on cognitive measures of working memory transfer to classroom outcomes (Shipstead et al., 2012; Tidwell et al., 2014). A recent meta-analysis examining research completed with children diagnosed with ADHD, concluded that the studies were often methodologically poor and most showed little impact on students' behavioural, cognitive or academic skills (Rapport, Orban, Kofler, & Friedman, 2013). A large-scale randomized evaluation of CogMed by Roberts and colleagues (2016) in Australia, with the evaluation extended across two years, found temporary improvements in visuo-spatial short-term memory, but no long-term benefits, and no change in academic skills, or wellbeing outcomes

More generically, researchers and writers have provided guidelines for teachers to have greater awareness of students' working memory difficulties and to embed attention and working memory adjustments in the classroom context (e.gs, Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2007, 2008). They argue cogently that the educational environment is particularly important to the development of working memory. In addition, Roberts et al.'s (2015) research found that the development of working memory is closely related to the time that students spend in a classroom environment, independent of and in addition to changes observed with increases in chronological age. Holmes, Gathercole, and Dunning (2010) summarised key principles that can be embedded within a classroom, with the focus on teacher awareness, monitoring and adjustments, particularly aiming to reduce working memory load. They emphasised the notion of the teacher directly helping children with self-supporting strategies, such as concrete memory aids, asking for help, rehearsing information, and making links to previous information. Several of these strategies parallel those depicted in Memory Mates, where they are presented with icons and explanations (Sheldon & Davis, 2013, as cited in Colmar et al., 2016). It is predicted that students may be able to make greater gains in their working memory capacity and use their working memory skills more often and with greater and broader facility, by following a specific intervention program, such as Memory Mates, within their familiar classroom context, where multiple opportunities arise for using attention and working memory skills (Colmar & Double, 2017).

Despite the wide availability of guidelines for incorporating working memory strategies in the classroom (e.gs, Alloway, 2011; Dehn, 2008; Gathercole & Alloway, 2007, 2008), to date there has been very little classroom-based research and no research providing students themselves with a specific, student-focused attention and working memory program, as occurs in the present study. Importantly the present study also includes normally developing students attending regular classrooms.

Further, the only two published teacher-focused, classroom-based interventions have had limited success at improving working memory and academic skills (Davis et al, 2014; Elliot et al., 2010). Elliot and his colleagues implemented an experimental study using either a teacher-directed, classroom-based working memory approach, or an academically targeted precision teaching approach, with an additional control group. Neither intervention significantly increased either working memory capacity or scores on standardised academic tests compared with the control group. Davis et al. (2014) implemented strategies through teacher training for students with low working memory within a classroom, noting important increases in students' on-task behaviour. However, as there was no experimental control, these data cannot be definitively attributable to the intervention.

The limited effectiveness of these two previously researched classroom interventions may have been, in part, because the classroom teacher was the focus, rather than the students. There are a number of reasons to hypothesise that a student-focused classroom intervention would be more successful, particularly when their teacher is also trained in appropriate classroom oriented adjustments to enhance attention and working memory strategies for all students, and also trained to support the students' individual use of attention and working memory strategies. Firstly, students have been found to display realistic insight into their working memory failures (Alloway, 2006), whereas teachers may not recognise the nature of specific working memory problems (Normand & Tannock, 2014). Secondly, there is evidence that suggests that allowing students to self-direct and become independent in managing their own learning is beneficial to academic outcomes (Sitzmann & Ely, 2011) and classroom engagement (Boekaerts & Corno, 2005). We hypothesised that if students were supported in self-reflecting on their own working memory challenges, within a classroom environment where the teacher realistically monitors and normalises limits to working memory for all students, and that this occurred in a classroom providing students with access to a choice of attention and working memory strategies, positive academic achievement outcomes as well as increased classroom engagement would occur.

In a pilot research project using the Memory Mates program with two classes in one school, no change in academic performance outcomes was observed (Colmar et al., 2016), probably because of the short (five weeks) period of intervention, which was insufficient for measurable academic change. However, teacher, students and parents' feedback were very positive and assisted in the further development of the program. Interestingly, this classroom-based Memory Mates program also included specific student reported generalisation of the strategies in home and community settings, including sporting activities, dancing, and giving their parents advice for remembering, as well as application in completing homework.

The present study evaluated Memory Mates with Year 4 students (fifth year of schooling) in 13 classrooms across six schools, with random allocation to the intervention or the waiting list control group. Memory Mates involves training students themselves to independently use ten key strategies derived from research and literature on attention and working memory in children (e.gs., Alloway & Alloway, 2013; Dehn, 2008, 2013; Gathercole & Alloway, 2007, 2008; Titz & Karbach, 2014) to enable better working memory functioning and to avoid working memory overload. In addition, Memory Mates includes three strategies specifically related to attention, ensuring students are appropriately focussed in order to utilise effective working memory strategies. The intervention provided access to a range of strategies targeted at and, importantly, also owned by the students (see Figure 1, Method), and assists students by having the classroom teacher communicate and provide assistance to students in using them. To support this process, Memory Mates is available as a website (www.memorymates.education), which gives the teacher updated skills and knowledge about facilitating attention, working memory and academic engagement. In turn, the teacher can create an individualised high quality, teaching environment that facilitates students' independent use of attention and working memory strategies.

It was hypothesised that by using a student-focused working memory intervention, students will better utilise and develop their working memory capacity and skills, and this will in turn lead to practical, measurable outcomes in academic performance and classroom engagement. An additional evaluative aspect of the intervention was to collect teacher and student feedback in order to develop and adapt the Memory Mates program for future use.

Method

Participants

The principals of six schools located in Sydney, Australia, agreed to participate in the research project. The Year 4 classes from each school and their respective teacher participated in the study, resulting in two classes from five schools and three classes from one. Three of the schools were randomly allocated to the experimental condition and three acted as controls. A randomisation check was performed, which indicated that the control and experimental groups did not differ significantly in terms of age or gender. In addition, teachers' ratings on the Working Memory Rating Scale (WMRS; Alloway, Gathercole, & Kirkwood, 2008) were analysed and the findings indicated that there were no pre-existing differences between the control and experimental groups in terms of working memory levels (all $p > .05$). A total of 309 students participated in the study, 152 in the experimental group and 157 in the control group (M_{Age} = 8.95, SD = .443; 48% male, 52% female). Primary language spoken at home was surveyed for each student; 61% spoke English, 13% Mandarin, 9% Greek, 6% Arabic and 11% spoke another language. Statistical tests were conducted on participants' demographic information and it was found that the two conditions did not significantly differ in relation to age ($t(305) = -.429$, $p = .668$), gender ($t(306) = -.899$, $p = .369$), or first spoken language ($t(300) = -1.944$, $p = .053$). Those students who were identified as having severe intellectual or English language speaking difficulties by the classroom teacher were excluded from the study but not from classroom participation; otherwise, all students whose parents provided consent participated in the study.

Materials

Memory Mates Materials. A prompt card with all ten Memory Mates strategies was created with a visually relevant icon and an appropriate explanation (see Figure 1). A4 sized cards of each Memory Mate strategy were created for teachers in the experimental condition to place prominently on classroom walls to aid their use of the intervention. Each child in the experimental condition was also supplied with two laminated A4 sized cards with all 10 Memory Mates on it, one for use at school and one for use at home. An A5 sized 'Forgotten Card' was also provided for pairs of students placed on their school desk.

<insert *Figure 1.* Memory Mates icons with explanations about here>

Working Memory difficulties. In order to measure existing differences in working memory prior to commencing the experimental intervention, the WMRS was administered. The WMRS is a 20 item-questionnaire completed by the teacher of each student. Teachers rate their students on a 4-point Likert scale from 'Not Typical At All' to 'Very Typical' on behaviours characteristic of working memory difficulties such as '*Frequently asks for help*' and '*Requires regular repetition of instructions*'. A higher score on this measure is indicative of more working memory problem behaviours. The reliability obtained for this scale in this sample was .98 (Cronbach alpha), which is very high.

Academic Achievement. Academic achievement was measured for mathematics using the Progressive Achievement Tests in Mathematics Fourth Edition (PAT-Maths, Australian Council for Educational Research [ACER], 2013). This is a 35-item test with well-established internal reliability (.89) and little gender differences. Reading achievement was assessed using the Progressive Achievement Tests in Reading Comprehension Fourth Edition (PAT-Reading, ACER, 2008), a 30-item test also with high internal reliability (.88). Finally, spelling achievement was measured using the Dalwood Spelling Test (DST; Dalwood Assessment Centre, 2008), again with a high reported reliability (.97).

Classroom Engagement. Classroom engagement was measured using two separate scales from the International Association for the Evaluation of Educational Achievement: one to assess mathematics engagement and one to assess reading engagement. Mathematics engagement was measured using the Students Engaged in Mathematics Lessons Scale (2011), which was used in the Trends in International Mathematics and Science Study [TIMSS]. Reading engagement was assessed using the Students Engaged in Reading Lessons Scale (Progress in International Reading Literacy Study [PIRLS], 2011). On both scales, students rated on a 4-point Likert scale from 'Agree a lot' to 'Disagree a lot' statements that gauged their classroom engagement, such as *'I am interested in what my teacher says'* and *'I think of things not related to the lesson'*. Reverse scoring was applied to selected items.

Procedure

After obtaining necessary ethical approvals and consents, pre-intervention testing of academic achievement (mathematics, reading, spelling), classroom engagement and working memory problems was carried out across two different days to ensure the attention and well-being of the children was maintained. The order of test administration was balanced. The PAT academic achievement tests (mathematics and reading) were conducted on a different day to the matching engagement questionnaire, so that any difficulties experienced by a student during the achievement test would be unlikely to negatively affect their engagement questionnaire responses. The WMRS was given to teachers on the first day of testing in their school for them to complete and return on the second day of testing.

Once the pre-intervention testing had been conducted in all six schools, the teachers who were participating in the experimental condition were individually trained in the use of the Memory Mates intervention by a School Psychologist, who is a member of the Memory Mates team. Training consisted of explaining each of the Memory Mate strategies and also how they could support students in using the strategies in a classroom context. Following this, the teachers then taught the Memory Mates strategies to their students, and throughout the following eight months they encouraged and reminded students to use the strategies, with copies displayed in the classroom as well as owned by every student. Teachers in the six experimental classrooms were able to contact the researchers as needed, and formal mentoring visits were carried out after approximately four months. After eight months implementing the Memory Mates program, the experimental and control schools' post-intervention testing was completed, following an identical format to the pre-intervention testing.

Results

Analyses compared the change over the school year in academic performance and classroom engagement between the intervention and control groups. The data was analysed using Statistical Programme for the Social Sciences, version 21.0 (SPSS). For each of the dependent variables a 2 (time: pre vs. post intervention) x 2 (group: intervention vs. control) mixed, between-within subjects' ANOVA was performed. In order to maximise statistical power, participants were included in all analyses in which they provided the appropriate data at *both* pre and post testing. The results are presented in Tables 1 and 2.

Academic Achievement

The mixed ANOVAs revealed a significant main effect for time, such that over the period of the study, there was a significant improvement (averaged across intervention and control groups) in each of mathematics, $F(1, 258) = 42.89$, $p < .001$, reading, $F(1, 257) = 45.65$, $p < .001$, and spelling, $F(1, 257) = 84.52$, $p < .001$.

<insert Table 1 about here>

Of greater interest to the present study was the Group x Time interaction. The ANOVAs revealed that mathematics, $F(1,258) = 4.27$, $p = .040$ improved significantly more in the intervention group compared to the control group, as did spelling $F(1, 257) = 3.89$, $p = .050$. However, with respect to reading achievement the Group x Time interaction was not significant ($p = .305$) indicating that there was no significant difference in reading comprehension between the intervention and control groups.

Classroom Engagement

Again, the same model was applied using the (mathematics and reading) engagement scales as dependent variables. Maths engagement did not significantly improve over the year ($p = .071$). However, the ANOVAs indicated that reading engagement improved over the course of the school year (averaged across experimental and control groups), $F(1,256) = 4.74$, $p = .030$. The ANOVAs further revealed that there was no significant Group x Time interaction for either mathematics engagement ($p = .565$) or reading engagement ($p = .657$).

<insert Table 2 about here>

Discussion

The present study evaluated the effectiveness of a novel classroom-based working memory training intervention named Memory Mates. The results showed that a student-focussed working memory program led to improvements in children's mathematics and spelling achievement. However, there was no significant effect of the intervention on reading comprehension or classroom engagement. The findings suggest that integrating working memory strategies into the classroom may provide a beneficial alternative to computerised training programs, which have struggled consistently to demonstrate transfer to academic outcomes (Colmar & Double, 2017; Roberts et al., 2016; van der Donk, Hiemstra-Beernink, Tjeenk-Kalff, van Der Leij, & Lindauer, 2013). Further, the present study is the first to specifically introduce student-oriented working memory strategies for whole classes rather than targeting students with difficulties in working memory. An additional benefit of this approach is that working memory challenges are normalised and contextualised as an experience common to all students, although at different levels of task complexity. The program also provided teachers with training and materials to support the implementation of Memory Mates with contextual and strategic adjustments (Sheldon, Davis & Colmar, 2015).

Our findings support the potential for classroom-based working memory interventions based around the provision of attention and working memory strategies to students so that they can self-manage these cognitive skills, by utilising and also practicing known strategies more frequently and by making use of newly acquired strategies. For the students, to some extent their "ownership" of the strategies function to support and encourage metacognitive awareness and insight into their own attention and learning skills, although they were derived from the academic working memory literature. Recent research confirmed that the specific addition of metacognitive strategy training to working memory training enhanced the latter (Jones, Milton, Mostazir, & Adlam, 2019).

The observed benefit to academic performance is unsurprising given the importance of attention and working memory as cognitive functions highly associated with academic performance (Alloway & Alloway, 2010; Engle, Carullo, & Collins, 1991). Specifically, the findings lend support to the previously reported results that working memory is predictive of mathematics and spelling achievement (Bull & Scerif, 2001). The lack of an observed effect of the training on reading comprehension is likely due to the fact that reading comprehension is a more stable and developmentally complex achievement (Ehri, 2005). Interestingly, reading engagement was significantly better across all students in both experimental and control classrooms, possibly making a difference in reading achievement less likely to occur in the intervention group. Indeed, the intervention appeared to have no significant effect on classroom engagement, suggesting that any academic benefits were unlikely to have been driven by changes in classroom engagement.

However, students responded well and showed considerable insights about their own attention and working memory processes, suggesting that directly providing students with appropriate strategies within the classroom context is an important and currently under-researched approach. Students may be able to make greater gains in their working memory capacity and use their working memory skills more often, and with greater and broader facility, by following a specific intervention program.

It is important to emphasise that Memory Mates targets attention and working memory strategies, rather than training a hypothesised underlying cognitive capacity. Traditionally, strategy training has been favoured; however, the proliferation of computerised cognitive training and some early research support (e.g. Jaeggi, Buschkuehl, Jonides, & Perrig, 2008) has led to a rise in training programs designed primarily to improve the capacity of working memory. Demonstrating transfer to academic outcomes from changes in the capacity of cognitive abilities such as working memory has, however, proven difficult (for reviews see Melby-Lervåg & Hulme, 2013; Shipstead et al., 2012). While the present findings do not speak to the effectiveness of such programs, or to the potential importance in training underlying cognitive capacities, these results do suggest that strategy training, which is directly relevant within the classroom context, may be an effective option and the benefits may readily transfer directly to academic outcomes. Of course, capacity training and strategy training are not mutually exclusive, and a combination of these training methods may prove effective.

Compared with computerised capacity training, classroom-based interventions benefit from the fact that they are directed by, and can be adapted and individualised by the teacher, and operate within the classroom environment. Computer-based training programs are generally highly autonomous and independent, and therefore are likely to require a high level of student self-regulation and motivation for learning (Sitzmann & Ely, 2011). However, since working memory is a crucial component of self-regulation (Hofmann, Friese, Schmeichel, & Baddeley, 2011), students who present with working memory problems (who may need the intervention most) are perhaps least likely to benefit from computerised training, due to its self-regulation requirements. This fact further strengthens the case for classroom-based interventions, particularly the Memory Mates program where students use the strategies within context and make choices about which strategy applies best for their needs at that time (Colmar & Double, 2017).

Research into the efficacy of classroom-based attention and working memory interventions is rare, largely due to the cost and time requirements. Of the three, classroom-based working memory interventions, prior to the present study, that have been evaluated, there has been little success in improving scores on standardised testing (Colmar et al., 2016; Davis et al., 2014; Elliot et al., 2010). Our findings suggest that incorporating student-focused aspects into an attention and working memory intervention program may be crucial to its success and the use of student-led strategies, such as those provided in Memory Mates, may have significant potential. However, this does not devalue the significant role that teachers have in facilitating and guiding working memory training, a claim that has been previously argued by a number of researchers (e.g. Aronen, Vuontela, Steenari, Salmi, & Carlson, 2005; Colmar et al., 2016; Elliot et al., 2010; Gathercole & Alloway, 2007). In the present study, separating existing teacher skills from the program's implementation across a long (eight month) intervention period was difficult and, in common with the work of Elliott et al. (2010), we acknowledge that effective teachers may engage in the teacher role described in Memory Mates (Sheldon et al., 2015) quite naturally without additional training. However, given these promising findings using Memory Mates, including teachers' and students' positive response to the program, more research into the viability of student-focused, classroom-based attention and working memory programs is warranted. Further, from data collected from students' feedback sheets and teacher interviews, participation and commitment to using the Memory Mates within each classroom was positive, with students' comments showing considerable metacognitive insights. In common with Jones et al. (2019), who specifically trained metacognitive strategies alongside working memory strategy training, Memory Mates led to spontaneously metacognitive understandings and to generalisation of attention and working memory skills to other contexts, such as home. Undoubtedly these arose in part from teacher input in introducing the strategies to the students, as well as independent deductions by individual students.

As our data also confirmed, simply being taught in a classroom across eight months, leads to concomitant academic learning across all academic areas for all students and increased reading engagement (but notably not mathematics engagement). These findings are encouraging in showing that schooling leads to progress regardless of additional interventions, and these data parallel Elliot et al.'s (2010) results, and link to Roberts et al.'s conclusion that schooling impacts working memory over and above chronological age changes.

Limitations and Future Directions

There were limitations of the present study, such as the lack of treatment fidelity; however, given the implementation was within six primary school classrooms across eight months, and a sample of seven classrooms that was not different (there were no pre-existing differences between the control and experimental groups in terms of working memory levels [all $p > .05$]) formed the control group, the findings remain of interest.

Another key limitation was having the seven-class, waiting list control group rather than having an active control group. There are constraints in implementing a study within the natural setting of classrooms, and one limitation was the lack of a viable active alternative to Memory Mates that would not be harmful and would be relevant for the control group teachers and students to participate in. No such alternative was available within our resourcing. We also viewed the wait list control group as the most ethical approach, such that these schools, parents and students, who were sufficiently motivated about the prospective possibility of Memory Mates to participate in pre and post testing, would also receive this intervention.

As a future direction, our research, coupled with the work of Jones et al. (2019), strongly support adding specific metacognitive training, in addition to allowing students to discuss and record their strategy use, may enhance the program's effectiveness. Anecdotally, we noted that students at this stage of schooling (Year 4) showed considerable interest in how their brains and learning worked.

The present study has provided much needed research into the effectiveness of a student-focussed, classroom-based attention and working memory intervention and the findings provide preliminary evidence that the Memory Mates training program has the potential to increase academic performance outcomes. Certainly, it is freely available (contrasting with the expensive CogMed program, which does not lead to generalisation across time or transfer of skills; Roberts et al., 2016). Memory Mates is closely aligned to teacher instructions and learning tasks that occur frequently in classroom contexts. While further research and replication is necessary before stronger conclusions can be drawn, these results are encouraging and provide a solid basis for further study and the continuing development of the program.

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References

ACER. (2008). *Progressive achievement tests in reading: Comprehension, vocabulary and spelling* (4th ed.). Melbourne ACER Press

ACER. (2013). *Progressive achievement tests in mathematics (PAT-Maths)* (4th ed.). Melbourne, Australia: ACER.

Ackerman, P. L., Beier, M. E., & Boyle, M. O. (2005). Working memory and intelligence: The same or different constructs? *Psychological Bulletin, 131*(1), 30-60. doi: 10.1037/0033-2909.131.1.30

Alloway, T. P. (2006). How does working memory work in the classroom? *Educational Research and Reviews, 1*(4), 134-139.

Alloway, T. P. (2009). Working memory, but not IQ, predicts subsequent learning in children with learning difficulties. *European Journal of Psychological Assessment, 25*, 92-98.

Alloway, T. P. (2011). *Improving working memory. Supporting students' learning*. London, England: Sage Publications Ltd.

Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology, 106*(1), 20-29. doi: http://dx.doi.org/10.1016/j.jecp.2009.11.003

Alloway, T. P., & Alloway, R. G. (2013). Working memory across the lifespan: A cross-sectional approach. *Journal of Cognitive Psychology*, 25(1), 84-93. doi: 10.1080/20445911.2012.748027

Alloway, T. P., & Copello, E. (2013). Working memory: The what, the why, and the how. *The Australian Educational and Developmental Psychologist, 30*(2), 105-118. doi: 10.1017/edp.2013.13

Alloway, T. P., Gathercole, S. E., & Kirkwood, H. (2008). *Working Memory Rating Scale (WMRS).* London, England: Pearson Education.

Alloway, T. P., Gathercole, S. E., Kirkwood, H., & Elliott, J. (2009). The cognitive and behavioral characteristics of children with low working memory. *Child Development*, *80*(2), 606-621. doi: 10.1111/j.1467-8624.2009.01282.x

Apter, B. J. B. (2012). Do computerised training programmes designed to improve working memory work? *Educational Psychology in Practice, 28*(3), 257-272. doi: 10.1080/02667363.2012.712915

Aronen, E. T., Vuontela, V., Steenari, M-R., Salmi, J., & Carlson, S. (2005). Working memory, psychiatric symptoms, and academic performance at school. *Neurobiology of learning and memory, 83*(1), 33-42.

Baddeley, A. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4*, 417-423.

Boekaerts, M., & Corno, L. (2005). Self-regulation in the classroom: A perspective on assessment and intervention. *Applied Psychology: An International Review, 54*, 199-231.

Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematics ability: Inhibition, switching, and working memory. *Developmental Neuropsychology, 19*(3), 273-293. doi: 10.1207/S15326942DN1903_3

Colmar, S. (2013). Attention and working memory. *APACS NSW ENewsletter, Term 4, 3*

Colmar, S. (2016) Memory Mates: An update. *APACS NSW ENewsletter, Term 2*

Colmar, S., Davis, N., & Sheldon, L. (2016). A pilot classroom-based study of attention and working memory strategies for primary aged students. *Journal of Psychologists and Counsellors in Schools, 26,* 1-12. doi 10.1017/jgc.2016.10

Colmar, S., & Double, K. (2017). Working Memory interventions with children: Classrooms or computers? *Journal of Psychologists and Counsellors in Schools,* 1-14. doi:10.1017/jgc.2017.11

Dalwood Assessment Centre (2008). *Dalwood spelling test*. Seaforth, Australia: Authors

Davis, N., Sheldon, L., & Colmar, S. (2014). Memory mates: A classroom-based intervention to improve attention and working memory. *Australian Journal of Guidance and Counselling, 24*(1), 111-120.

Dehn, M. J. (2008). *Working memory and academic learning: Assessment and intervention*. Hoboken, N. J.: John Wiley & Sons.

Dehn, M. J. (2013). Supporting and strengthening working memory in the classroom to enhance executive functioning. In S. Goldstein & J. A. Naglieri (Eds.), *Handbook of executive functioning* (pp. 495-507). New York, NY: Springer.

Ehri, L. C. (2005). Development of sight word reading: Phases and findings. In M. J. Snowling & C. Hulme (Eds.), *The science of reading: A handbook.* (pp. 135-154). Malden, England: Blackwell.

Elliott, J. G., Gathercole, S. E., Alloway, T. P., Holmes, J., & Kirkwood, H. (2010). An evaluation of a classroom-based intervention to help overcome working memory difficulties and improve long-term academic achievement. *Journal of Cognitive Education and Psychology, 9*(3), 227-250.

Engle, R. W., Carullo, J. J., & Collins, K. W. (1991). Individual differences in working memory for comprehension and following directions. *The Journal of Educational Research, 84*(5), 253-262. doi: 10.1080/00220671.1991.10886025

Gathercole, S. (2008). Working memory in the classroom. *The Psychologist*, 21(5), 382-385.

Gathercole, S. E., & Alloway, T. P. (2007). *Understanding working memory: A classroom guide*. London, England: Harcourt Assessment.

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

Gathercole, S. E., Lamont, E., & Alloway, T. P. (2006). Working memory in the classroom. In S. J. Pickering (Ed.), *Working memory and education* (pp. 219-240). London, England: Elsevier Press.

Hofmann, W., Friese, M., Schmeichel, B. J., & Baddeley, A. D. (2011). Working memory and self-regulation. In Kathleen D. Vohs & R. F. Baumeiste (Eds.), *The handbook of self-regulation: Research, theory, and applications* (2 ed., Vol. 2, pp. 204-226). New York, NY: Guilford Press.

Holmes, J., Gathercole, S. E., & Dunning, D. L. (2010). Poor working memory: Impact and interventions. In J. Holmes (Ed.), *Advances in child development and behavior* (Vol. 39, pp. 1-43). Burlington, VT: Academic Press.

Hulme, C., & Melby-Lervåg, M. (2012). Current evidence does not support the claims made for CogMed working memory training. *Journal of Applied Research in Memory and Cognition, 1*(3), 197-200. doi: http://dx.doi.org/10.1016/j.jarmac.2012.06.006

International Association for the Evaluation of Educational Achievement (2011). *Students engaged in mathematics lessons scale* Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College and International Association for the Evaluation of Educational Achievement (IEA), IEA Secretariat, Amsterdam, the Netherlands.

International Association for the Evaluation of Educational Achievement (2011). *Students engaged in reading lessons scale.* Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College and International Association for the Evaluation of Educational Achievement (IEA), IEA Secretariat, Amsterdam, the Netherlands.

Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Perrig, W. J. (2008). Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences*, 105(19), 6829-6833. doi: 10.1073/pnas.0801268105

Jones, J. S., Milton, F., Mostazir, M., & Adlam, A. L. R. (2019). The academic outcomes of working memory and metacognitive strategy training in children: A double-blind randomized controlled trial. *Developmental Science*. doi.org/10.1111/desc.12870

Klingberg, T. (2010). Training and plasticity of working memory. *Trends in Cognitive Sciences, 14*, 317-

324.

Klingberg, T., Fernell, E., Olesen, P. J., Johnson, M., Gustafsson, P., Dahlstrom, K., . . . Westerberg, H. (2005). Computerized training of working memory in children with ADHD-- A randomized, controlled trial. *Journal of the American Academy of Child & Adolescent Psychiatry, 44*, 177-186.

Melby-Lervag, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental Psychology, 49*, 270-291.

Monette, S., Bigras, M., & Guay, M-C. (2011). The role of the executive functions in school achievement at the end of Grade 1. *Journal of Experimental Child Psychology, 109*(2), 158-173.

Morrison, A. B., & Chein, J. M. (2011). Does working memory training work? The promise and challenges of enhancing cognition by training working memory. *Psychonomic Bulletin & Review, 18*(1), 46-60.

Normand, S., & Tannock, R. (2014). Screening for working memory deficits in the classroom: The psychometric properties of the working memory rating scale in a longitudinal school-based study. *Journal of Attention Disorders, 18*(4), 294-304. doi: 10.1177/1087054712445062

Pickering, S. J. (2006). Working memory in dyslexia. In T. P. Alloway & S. E. Gathercole (Eds.), *Working memory and neurodevelopmental disorders* (pp. 7-40). New York, NY: America Psychology Press.

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*(8), 1237-1252. doi: http://dx.doi.org/10.1016/j.cpr.2013.08.005

Re, A. M., Mirandola, C., Esposito, S. S., & Capodieci, A. (2014). Spelling errors among children with ADHD symptoms: The role of working memory. *Research in Developmental Disabilities, 35*, 2199-2204.

Redick, T. S., Shipstead, Z., Wiemers, E. A., Melby-Lervåg, M., & Hulme, C. (2015). What's working in working memory training? An educational perspective. *Educational Psychology Review*, 1-17.

Roberts, G., Quach, J., Mensah, F., Gathercole, S. E., Gold, L., Anderson, P., . . . Wake, M. (2015). Schooling duration rather than chronological age predicts working memory between 6 and 7 years: Memory Maestros study. *Journal of Developmental and Behavioral Pediatrics, 36*, 68-74. doi: 10.1097/DBP.0000000000000121.

Roberts, G., Quach, J., Spencer-Smith, M., Anderson, P. J., Gathercole, S., Gold, L., . . . Wake, M. (2016). Academic outcomes 2 years after working memory training for children with low working memory. *JAMA Pediatrics, 170,* online. doi:10.1001/jamapediatrics.2015.4568

Rode, C., Robson, R., Purviance, A., Geary, D. C., & Mayr, U. (2014). Is working memory training effective? A study in a school setting. *PLoS ONE, 9*(8), e104796.

Sheldon, L., Davis, N., & Colmar, S. (2015). *Memory Mates: A classroom-based intervention to improve attention and working memory in primary-aged students.* Sydney, Australia: Authors.

Shipstead, Z., Redick, T. S., & Engle, R. W. (2012). Is working memory training effective? *Psychological Bulletin, 138*(4), 628-654.

Sitzmann, T., & Ely, K. (2011). A meta-analysis of self-regulated learning in work-related training and educational attainment: What we know and where we need to go. *Psychological Bulletin, 137*(3), 421.

Tidwell, J. W., Dougherty, M. R., Chrabaszcz, J. R., Thomas, R. P., & Mendoza, J. L. (2014). What counts as evidence for working memory training? Problems with correlated gains and dichotomization. *Psychonomic Bulletin & Review, 21*(3), 620-628.

Titz, C., & Karbach, J. (2014). Working memory and executive functions: Effects of training on academic achievement. *Psychological Research, 78*(6), 852-868.

van der Donk, M., Hiemstra-Beernink, A.-C., Tjeenk-Kalff, A., van der Leij, A., & Lindauer, R. (2013). Interventions to improve executive functioning and working memory in school-aged children with AD(H)D: A randomised controlled trial and stepped-care approach. *BMC Psychiatry, 13*(1), 23.

Witt, M. (2011). School based working memory training: Preliminary finding of improvement in children's mathematical performance. *Advances in Cognitive Psychology, 7*, 7-15. *Figure 1.* Memory Mates icons and explanations

memory mates®

switch on

- Is my brain switched on?

listen

- Listen to the teacher's instructions

download

- Put the teacher information into my brain

picture it

- Create a picture of the activity in my mind

memory coach

- Talk to my memory coach about the activity

link

- What can I link this to?

self talk

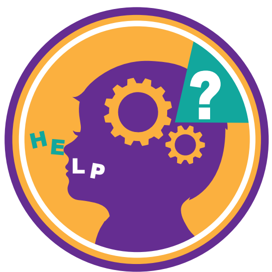
- Say it again to myself

memory aids

- What things can I do to help remember?

time check

- How fast am I going?



forgotten?

- Look at the board
- Re - read the instructions
- Ask my memory coach
- Ask the teacher for help

Table 1

Mean Test Scores for Maths, Reading and Spelling Academic Achievement at Pre and Post Intervention as a Function of Experimental Group

	Experimental Classroom			Control Classroom		
Means (SD)	Maths	Reading	Spelling	Maths	Reading	Spelling
Pre-intervention	23.33 (6.51)	19.12 (6.31)	66.72 (12.31)	25.28 (6.44)	20.82 (5.83)	69.32 (12.41)
n	143	146	143	151	153	151
Post-Intervention	25.39 (6.79)	20.91 (6.30)	70.29 (13.49)	26.38 (6.70)	23.15 (5.64)	72.04 (12.69)
n	129	128	128	144	136	144

Table 2

Mean Test Scores for Maths and Reading Engagement at Pre and Post Intervention as a Function of Experimental Group

	Experimental Classroom		Control Classroom	
Means (SD)	Maths	Reading	Maths	Reading
Pre-intervention	16.67 (2.82)	23.35 (3.56)	16.56 (2.73)	22.83 (3.37)
n	145	143	147	151
Post-Intervention	16.60 (2.84)	22.71 (4.06)	16.27 (3.00)	22.43 (3.88)
n	128	126	135	144