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Computerised working memory training: Evidence against near- and far-transfer effects in Icelandic primary school children

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40 eininga lokaverkefni á áherslusviðinu Nám og margbreytileiki - sérkennslufræði
sem er hluti af
Magister Artium-prófi í menntavísindum

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Abstract

The effectiveness of computerised working memory training programs in enhancing performance on untrained tasks is a controversial topic with potential implications in educational contexts. Here, we describe a small-scale intervention study undertaken with 16 typically-developing Icelandic students in the third grade, in which we aimed to shed light on whether adaptive working memory training in a form of computer games (Cogmed) was only beneficial to near transfer tasks like similar working memory tasks or if it would also benefit performance onfar transfer tasks, more relevant to educational settings, like reading comprehension, word decoding, and improvements of control of attention. The research used a single-blind, intervention design with pre- and post-intervention measurements of dependent variables. Students were assigned either to an intervention group or an active control group. Five dependent variables were measured: word decoding, reading comprehension, visuo-spatial working memory, visual working memory, and attention. The working memory tasks were classified as near transfer tasks, and the others as far transfer tasks. Our data showed that, after 14-18 training blocks of RM Cogmed working memory training, students improved on one near transfer task (visual working memory) but not on the other (visuo-spatial working memory). However, results from the task showing improvement may have been skewed by a large pre-post difference in a single student in the intervention group. Our data provided weak evidence against the effectiveness of training on far transfer tasks like word decoding, reading comprehension, and attention. These findings add to the body of evidence suggesting that working memory training may not be useful in improving educational outcomes for typically developing children such as those studied here. Future research with larger samples could focus on the impact of working memory training on children with learning disabilities or diagnosed as having attention deficits.

Key words: working memory training - Cogmed - near and far transfer effects - attention- word decoding - reading comprehension

Ágrip

Bætt vinnsluminni gæti mögulega haft jákvæð áhrif á námsárangur en það er umdeilt hvort árangur vinnsluminnisþjálfunar yfirfærist á óskyld atriði þeim sem voru þjálfuð og hvort forrit sem hafa verið þróuð til að þjálfa vinnsluminni, virki í raun og veru. Hér er íhlutunarrannsókn lýst þar sem úrtakið voru 16 íslenskir nemendur án námsvanda í þriðja bekk. Tilgangur rannsóknarinnar var að varpa ljósi á hvort að einstaklingsmiðuð þjálfun á vinnsluminni í formi tölvuleikja (Cogmed) reyndist einungis árangursrík í nær yfirfærslu, verkefnum sem voru lík þeim sem voru þjálfuð eða hvort þjálfunin gagnaðist í fjær yfirfærslu, verkefnum sem voru meira í takt við almennt skólastarf, líkt og lesskilningur, umskráning og stjórn á athygli. Rannsóknin var einblind íhlutunarrannsókn með mælingum á fylgibreytum fyrir og eftir íhlutun. Nemendum var skipt í íhlutunarhóp eða virkan samanburðarhóp. Fimm fylgibreytur voru mældar, umskráning, lesskilningur, rýmisvinnsluminni, sjónrænt vinnsluminni og athygli. Vinnsluminnisverkefnin voru flokkuð sem nær yfirfærslu verkefni, en hin sem fjær yfirfærslu verkefni. Niðurstöður okkar gáfu til kynna að eftir 14-18 vinnulotur í RM Cogmed vinnsluminnisþjálfun sýndu nemendur framfarir í sumum nær yfirfærslu verkefnum eins og sjónrænu vinnsluminni en ekki í öðrum nær yfirfærslu verkefnum eins og rýmisvinnsluminni. Hins vegar gætu þessar framfarir verið tálsýn vegna mikils einstaklingsmunar á niðurstöðum í fyrir og eftir prófun hjá einum nemanda í íhlutunarhópnum. Niðurstöður okkar bentu ekki til árangurs vinnsluminnis þjálfunar í fjær yfirfærslu verkefnum eins og umskráningu, lesskilningi og athygli. Þessar niðurstöður styðja þær kenningar að vinnsluminnisþjálfun fyrir börn án námsvanda, eins og þau sem unnið var með hér, sé ekki árangursrík til að bæta námsárangur þeirra. Framtíðarrannsóknir með stærra úrtaki gætu einblínt á vinnsluminnis þjálfun á meðal barna með námsvanda eða þeirra sem greind eru með athyglisvanda.

Lykilorð: vinnsluminnis þjálfun - Cogmed - nær og fjær yfirfærsla - athygli - umskráning - lesskilningur

Formáli

Rannsókn þessi er 40 eininga (ECTS) meistaraprófsverkefni til MA. -prófs í menntavísindum á áherslusviðinu nám og margbreytileiki – sérkennslufræði við kennaradeild hug- og félagsvísindasviðs Háskólans á Akureyri. Leiðsögukennari var Peter Shepherdson og honum færi ég þakkir fyrir góða leiðsögn, hvatningu og stuðning. Ráðunautur var Árni Gunnar Ásgeirsson og þakka ég honum góðar ábendingar og yfirlestur.

Þeir nemendur sem tóku þátt í rannsókninni eiga hrós og þakkir skyldar sem og umsjónarkennarar þeirra, þær Halla Karlsdóttir og Daggrós Stefánsdóttir en án þeirra hjálpar hefði ekki verið hægt að klára þessa rannsókn. Hulda Þorbjarnardóttir á þakkir skyldar fyrir góða aðstoð með nemendur. Eygló Friðriksdóttur er þakkað fyrir hvatningu og stuðning. Án hennar stuðnings hefði ekki verið hægt að hefja þessa rannsókn.

Að lokum fær fjölskylda mín þakkir fyrir aðstoð og stuðning á meðan á náminu stóð. Eiginmanni mínum Andri Stefánssyni, er ég ómetanlega þakklát fyrir alla hjálpina og börnum mínum, þeim Hirti, Hlyni og Lilju þakka ég þolinmæðina.

Efnisyfirlit

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1. Introduction

Many cognitive tasks require the temporary storage and retrieval of information. For instance, consider the processes involved in reading a story: To make sense of the individual words we read, we need to integrate them with the context provided by the rest of the sentence; and to make sense of the sentence, we need to remember the context of the story itself. Another simple example of the necessity of temporary information storage is mental arithmetic: If one wants to multiply 23×3, one may first multiply 3×3 to obtain 9, then keep that result in mind and while multiplying 3×20 to obtain 60, before finally adding 9 to 60 to reach the right outcome of 69. Without the ability to temporarily store and manipulate information this process would not be possible. The system that is responsible for this process is called working memory (WM). In the study reported here, we aimed to assess the effectiveness of one proposed means of improving WM performance---namely, WM training---on a variety of tasks that depend on this system. We begin by describing a popular WM model before discussing variations in WM and WM training, asking how effective WM training is and then introducing our study itself.

1.1 Baddeley and Hitch´s Working Memory Model

The most well-known description of the WM system is derived from the work of Baddeley and Hitch. They described memory as being layered in several memory systems---long-term memory (LTM), short-term memory (STM) and working memory---with each system responsible for different operations (Baddeley, 2007). Long-term memory, as its name implies, is assumed to “underpin the capacity to store information over long periods of time” (Baddeley, Eysenck & Anderson, 2015, p.13). This can involve either explicit or declarative memory---referring to situations or specific events that we generally think of as involving memory, like meeting a friend unexpectedly last year or facts like the meaning of a word---and implicit memory---thought to be largely evident in skilled performance, like riding a bike or using language (Squire, 1992). By contrast, short-term memory is involved in the temporary storage of small amounts of material over brief delays (e.g., Atkinson & Shiffrin, 1968). Finally, working memory is theorised as a system that incorporates STM (e.g., Baddeley, Eysenck, & Anderson, 2015), but also involves processes other than simply storage. Specifically, the term is used to describe the system that underpins our capacity to keep things in mind when performing complex tasks (Baddeley, Eysenck & Anderson, 2015, p.12). Working memory has been described as the

> "brain´s processing system that allows us to mentally work with a limited amount of information in the now. It is fundamental to all advanced thinking and in order to learn facts or skills, that information must first pass through working memory—our mental workbench, before becoming more stable long-term representations"
> (Bergman Nutley & Söderqvist, 2017, p. 2).

Baddeley and Hitch (1974) proposed a multicomponent model of working memory consisting of three components: the phonological loop, assumed to be specialized for providing storage for verbal/acoustic material, the visuo-spatial sketchpad, assumed to perform similar storage for visual and spatial coding, and the central executive, an attentionally limited system that provides overall control. This presentation of the three-component model of working memory has been successful over the years, giving an integrated account not only of data from normal adults, but also neuropsychological, developmental and neuroimaging data (Baddeley, 2000). However, there are several phenomena that the original version did not readily capture. Baddeley (2000) therefore proposed a new component to the model of working memory, the episodic buffer, thereby attempting to explain how working memory was linked to long term memory. Baddeley describes the episodic buffer as a multidimensional store that is accessible to conscious awareness. Figure 1 demonstrates the current version of the multicomponent working memory model.

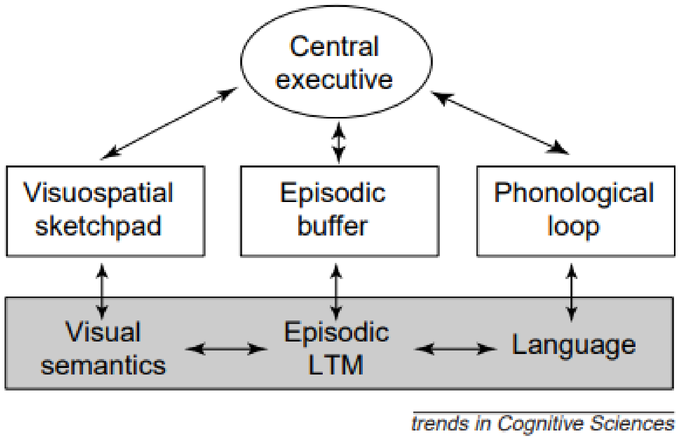

Figure 1 The current version of the multicomponent working memory model (Baddeley, 2000)

1.2 Variations in WM and WM training

As in all psychological traits, people vary in their memory abilities. However, given the importance of the WM system in complex cognition, variations in WM performance have been the subject of considerable research (e.g., Unsworth & Engle, 2007; Unsworth, Spillers, & Brewer, 2010). These differences are typically assessed with reference to the construct of working memory capacity, described as “an assessment of the how much information can be processed and stored at the same time” (Baddeley, Eysenck & Anderson, 2015, p.390), and which is thought to be predictive of performance in a wide range of cognitive tasks (Klingberg, 2010).

Recent research has suggested that verbal WM can be improved with intense verbal working memory training (Peng & Fuchs, 2017). The idea of training WM was originated by Torkel Klingberg, a Swedish neurologist who developed a training program he named Cogmed (www.cogmed.com), originally designed for use by children with attention deficit hyperactivity syndrome (ADHD; Klingberg et al., 2005), which some researchers have suggested reflects poor working memory (Holmes et al., 2010). In its current form, Cogmed training is presented in a format resembling a computer game, and contains a number of adaptive tasks, such that participants are working to their upper level of capacity even as their performance improves. Given the importance of WM in real-life situations such as reasoning, problem-solving, and decision-making (e.g., Del Missier et al., 2013; Hardman & Cowan, 2016; Shipstead, Harrison & Engle, 2016), WM training has since been expanded beyond the initial population targeted by Cogmed, and commercialised, with the aim of generating real-world benefits in a variety of populations. Since the early 2000s the public interest in brain training has grown rapidly and in consequence the commercial market for brain-training software has as well (Simons et al., 2016). Most brain-training companies operate in the United States and the best-known companies producing WM training products are Lumos Labs, Posit Science, Nintendo and Cogmed (Simons et al., 2016).

1.3 How effective is WM training?

Researchers working in the area have conflicting views about the effectiveness of WM training. However, most results are currently broadly in line with there being good evidence for an effect of training only on tasks similar to those directly trained, with limited evidence that WM training is useful in real-world environments. Though some researchers claim lasting effects of WM training on cognitive performance (e.g., Holmes, Gathercole & Dunning, 2009), the majority have found close relations between WM training and performance improvement on the trained task, less evidence that interventions improve performance on closely related tasks (i.e., near transfer), and minimal evidence that training enhances performance on distantly related tasks (i.e., far transfer) or that training improves everyday cognitive performance (e.g., Simons, 2016).

One example of a far transfer task relevant to educational settings that relies on WM is reading. Relations between working memory and reading ability appear to be complex. Some researchers have pointed out that differences in working memory capacity may be the source of individual differences in reading comprehension (Daneman & Carpenter, 1980). Others have demonstrated that different subsystems of working memory showed different correlations with the three assessed reading abilities: decoding, reading comprehension and reading time and the highest correlations of all reading abilities being with the phonological complex memory subsystem (Nevo & Breznitz, 2011).

The quality of the working memory's processing and storage functions appear to be decisive factors when separating a good reader from a bad one. An example of these processing functions is the so-called chunking process that recodes concepts and relations into higher orders units. One possibility is that good readers have higher-quality chunks than poor readers: The good reader's chunk is richer and more informative and since more information is stored in one unit that reduces the load on the working memory system, hence increasing the functional working capacity for subsequent processing (Daneman & Carpenter, 1980).

Working memory also plays a crucial role in the development of literacy among children with special needs, and interventions involving WM training have shown positive effects on reading comprehension (Dahlin, 2011). The evidence of an impact of working memory training on reading-relevant skills like phoneme awareness and letter knowledge has, however, not been as convincing (Foy & Mann, 2014). Such conflicting results raise the question of why training works in some cases and not in others. Why does training appear to be effective for reading comprehension, but not for phoneme awareness and letter knowledge, which are essential elements of word decoding? Given the suggestion of Simons et al. (2016) that the effectiveness of training is dependent on how closely the outcome measure resembles the training task, one possibility is that the processes involved in reading comprehension are similar enough to training tasks in WM training for training effects to transfer, whereas this is not the case for word decoding. For instance, the processes involved in retelling a story or answering questions about a story may be similar to the cognitive processes used when completing a simple digit span working memory task (hearing numbers read out loud and repeating them), such as use of the phonological loop. This is consistent with Dahlin's (2011) suggestion. By contrast, since decoding does not obviously require this component of WM, transfer to such a task would be less likely.

Research has also been conducted into the effects of specific WM training regimes on academically relevant outcomes. For instance, Roberts et al., (2016) tested whether the aforementioned computerized adaptive working memory intervention program, Cogmed, improved long- term academic outcomes of children 6 to 7 years of age with low working memory, with usual classroom teaching used as a control condition. Results demonstrated that out of the 4 short-term and working memory outcome variables measured, only one outcome (visuospatial-short term memory---a near transfer task) had improved in the intervention group children at 6- and 12-months post-intervention. No benefits were found for the primary outcomes, which were far transfer tasks such as word reading, spelling, math computation, and sentence comprehension. By contrast, evidence from other recent research using the same training program as an intervention, measuring similar outcomes on both near transfer tasks like working memory tasks (two-back task and a digit span task) and far transfer tasks like an intelligence test and academic scores (in Chinese and math), suggested that WM updating training could mitigate the cognitive deficits of learning disabilities and improve WM capacity, with the effects of training maintained for at least 6 months (Chen, Ye, Chang, Chen & Zhou, 2018). Thus, the generally ambiguous results concerning the effectiveness of WM training are also present when individual training regimes are considered.

There have also been suggestions that working memory training could induce improvements in attentional performance (e.g., Klingberg, 2010).

Given WM and attention are usually assumed to be related, this is perhaps unsurprising. However, there is still not a good understanding of how exactly working memory is related to attention, which may partly be a result of the different phenomena that the term or the concept “attention” is used to describe, and the different roles these play in WM. Oberauer (2019) outlines two distinct meanings: the first which characterises attention as a resource, and the second as a mechanism that allows the selective processing of information. In the former case the limitations to attentional resources are viewed as overlapping with the limited capacity of WM, whereas in the latter the main emphasis lies on the process used to select and prioritise information within WM. These two different conceptualisations suggest different strategies or at least different goals in the use of working memory training as an intervention to enhance or increase attention somehow, each of which corresponds to one of the potential mechanisms identified by Von Bastian and Oberauer (2014) as mediating transfer effects from working memory training. The first, enhanced working memory capacity (e.g., more items able to be maintained in WM), corresponds to the idea of attention as a limited resource; and the second, enhanced working memory efficiency, corresponds to the idea of attention as a process within WM. Distinguishing between effects on capacity and efficiency, and thus understanding the potential mechanisms by which any effects of WM training arise in attention, is not straightforward.

Thus, there remains substantial uncertainty concerning the effectiveness of WM training. Specifically, it is unclear whether WM training is only beneficial to tasks highly similar to those trained, or if the training can also be effective in less similar domains (e.g., attentional performance) or even in real-world contexts (e.g., for reading related abilities like decoding and phoneme awareness, or reading comprehension).

1.4 The present study

In the research described here, we attempted to shed further light on these issues by examining the effects of a specific WM training program on different aspects of students’ reading ability, as well as their attentional and WM performance. We aimed to determine whether WM training is only beneficial to near transfer tasks (e.g., similar WM tasks) or whether it can also be beneficial to far transfer tasks more relevant to educational settings, like reading comprehension and improvements of control of attention. Specifically, we investigated the impact of structured memory training on word decoding, reading comprehension, attention, and working memory itself. We classify the working memory tasks as near transfer tasks, and the word decoding, reading comprehension and attention tasks as far transfer tasks.

Given the ambiguity of the evidence referred to above, our expectations about the effects of training differ across these outcome tasks. Because of the lack of evidence that working memory training assists skills like phoneme awareness and letter knowledge (Foy & Mann, 2014), we expected that training would not affect decoding ability. By contrast, prior studies have shown positive effects of training on reading comprehension (Dahlin, 2011), some near transfer tasks like visuo-spatial working memory tasks (Roberts et al., 2016) and tasks assessing WM capacity (Chen, Ye, Chang, Chen & Zhou, 2018), and tasks measuring attention (Klingberg, 2010). We therefore expected positive effects from the training in the current study on reading comprehension, visuo-spatial working memory, visual working memory, and attention.

To investigate these relationships, we conducted a small-scale intervention study with primary school children. The children were quasi-randomly assigned to two groups: an intervention group, that received Cogmed computer-based working memory training, and an active control group, that completed other computer-based educational games not specifically designed to train working memory. Both groups were tested before and after the intervention period with a series of tasks measuring performance on reading comprehension, word decoding, visual working memory, visuo-spatial working memory, and visual attention. To pre-empt our findings, though the small sample size prevented us from gathering particularly strong evidence in favour of or against the effectiveness of WM training, our results showed limited differences between the two groups on most of the outcome tasks, suggesting that their performance is not enhanced by WM training.

2. Method

2.1 Participants

We recruited a sample of 16 children born in the year 2011 attending grade 3 in primary school in Reykjavík, Iceland. The class from which the children were recruited consisted of 38 children (n=38). Children that either received special education from a special education teacher at the time of intervention (n=9) or were going through a screening process of severe conduct disorder (n=1) were excluded from the selection process. Three children did not want to participate in the study after having read the introduction letter. A total of 13 children were therefore excluded from the sample but the remaining 25 children were available for assignment either to an intervention group (n=8) or an active control group (n=8). We used a matched assignment process, with recent academic records of reading words per minute and gender as the deciding factors, to allocate students to groups, with the aim of making them as homogeneous as possible. The initial allocation to the groups was random, but to ensure that the average group characteristics were roughly the same, some children were moved between groups afterwards.

2.2 Intervention tasks

Working memory training

The full Cogmed RM working memory training consists of a total of 12 visuo-spatial and verbal working memory tasks. Our pre-registered method was to exclude three tasks because of the English verbal instructions and the danger of 8-year-old Icelandic children not necessarily understanding the verbal instructions in those tasks (decoder, input module, and input module with lid). This would leave 9 exercises for our intervention. However, the input module and input module with lid tasks were among the first tasks in the first training blocks in the standardised training program that the students had to finish (standardised program is 25 minutes per block, total of 40 blocks). The children did not seem to have any problems understanding the instructions and these tasks were therefore also included. Ten tasks out of twelve were trained during the intervention period. The training was adaptive, meaning that the children were always working at the upper limit of their memory capacity, which is described in the Cogmed training manual (Pearson, 2014, p. 11) as a method thought to lead to improvements.

Cogmed working memory tasks

All of the tasks involve the presentation and reproduction of sequences whose length depends on the student's current performance level. Screenshots from the tasks are presented in Figure 2 followed by a closer description of each task.

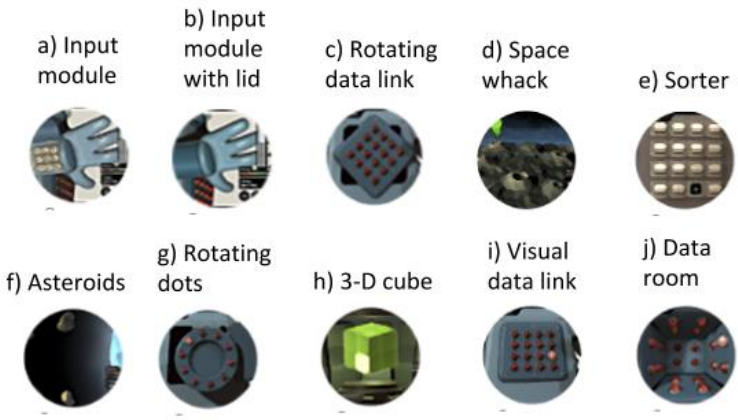

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Figure 2 Screenshots showing the different Cogmed Working Memory tasks, www.cogmed.com

Input module

A sequence of numbers is presented auditorily, and each number simultaneously highlighted in a visual array. To respond, the student taps the numbers in the reverse order of presentation upon conclusion of the sequence. For instance, if the sequence were 3, 8, 4, the correct response would be to tap 4, 8, 3. For illustration see panel a) in Figure 2.

Input module with lid

A sequence of numbers is presented auditorily, while a lid covers the visual number array so the student is not provided with supporting visual or spatial information. Upon conclusion of the sequence, the lid is raised, revealing the array. To respond, the student taps the numbers in reverse order of presentation. For illustration see panel b) in Figure 2.

Rotating data link

The student is presented with 16 red lamps arranged in a 4×4 grid on a panel. The lamps are highlighted in a sequence, and then the panel is rotated, before the student responds by tapping the highlighted lamps in forward order. For illustration see panel c) in Figure 2.

Space whack

The student is presented with a volcanic, outer-space landscape. The craters in the landscape erupt in sequence, and the student responds by tapping the craters in the order that they erupted. For illustration see panel d) in Figure 2.

Sorter

The student is presented with a closed keypad arranged in a 4×4 grid. The keys open one at a time to reveal unique positive integers. The student has to remember which number appeared on which key and responds by tapping in forward numerical order (as opposed to presentation order). For instance, if the sequence is 3, 1, 2, 4 a correct response would be to sequentially tap 1, 2, 3, 4. For illustration see panel e) in Figure 2.

Asteroids

Slowly moving asteroids are presented in space. They burst one at a time and the student is supposed to tap on them in forward serial order. For illustration see panel f) in Figure 2.

Rotating dots

Ten red lamps are presented on a wheel that continuously is spinning, with some number of the lamps lighting up in a sequence. The student responds by tapping on the dots in the order in which they were illuminated while the wheel continues to spin. For illustration see panel g) in Figure 2.

3-D cube

The student is presented with a green 3-D cube with each side being divided into four identical square segments. One segment per side is illuminated and the cube rotates as each side is presented, with the student seeing at least three sides of the cube over each course of a trial. The student then responds by tapping on the segments in the order in which they were illuminated. For illustration see panel h) in Figure 2.

Visual data link

16 red lamps are presented in a 4×4 grid and illuminated one at a time. The student responds by tapping the lamps in the same order as they were illuminated. For illustration see panel i) in Figure 2.

Data room

20 red lamps are presented in a room. The lamps are illuminated sequentially, and the student responds by tapping on the lamps in forward order. For illustration see panel j) in Figure 2.

Control tasks - educational games using tablets

The children in the control group worked with tablets and played educational games emphasizing different skills. Usually the first author (G.G.) introduced one game each day that was mandatory to play for a while or at least until all the children had gotten a good grasp of the game. These games were as follows.

Figure 3 Images of control tasks

Osmo numbers

A math game using physical tiles to count, add and multiply. The student places the tablet on a base that creates an interactive area in front of the tablet. Numbers in bubbles appear on the screen and the student has to put the correct number, using the physical tiles, in the interactive area to make the bubbles burst with a satisfying pop. For illustration see panel a) in Figure 3. For further detail see https://www.playosmo.com/en/shopping/games/numbers/.

Osmo Newton

A problem solving and physics game. The student places the tablet on a base creating an interactive area in front of it. The student has a whiteboard and a whiteboard pen in the interactive area. Balls appear on the screen and in order to get them to fall into the target zones the student needs to draw lines on the whiteboard. For illustration see panel b) in Figure 3. For further detail see https://support.playosmo.com/hc/en-us/articles/115010487848-What-is-the-Osmo-Newton-game-.

Garage band

A musical studio. The student can choose between various instruments and make music. For illustration see panel c) in Figure 3. For further detail see https://www.apple.com/mac/garageband/.

Þrír í röð

A math game. The student is presented with 36 different numbers in a 6×6 table and beneath it a multiplication example appears (e.g., 2×5). The student is then supposed to tap on the right outcome that is somewhere in the table above (e.g., 10). If the right outcome is tapped then the student gets a coloured disc to put over that number. Two students can compete with each other or the student can compete with the computer and the one who manages first to get three correct outcomes in a row wins the game. For illustration see panel d) in Figure 3. For further detail see https://vefir.mms.is/thrir_i_rod/.

Four in a row

A strategy game. The student takes turns against the computer dropping red or blue discs onto the board. The aim is to connect 4 pieces horizontally, vertically or diagonally to win. For illustration see panel e) in Figure 3. For further detail see https://www.coolmathgames.com/0-4-in-a-row.

Orðaleikurinn

A game training decoding ability. The student chooses a topic and is presented with a picture, some boxes and letters in random order. The student is supposed to place the letters in the right order [e.g., in the example displayed in Figure 3 the letters should be in the order H – Ú – S to form the word HÚS (house)]. For illustration see panel f) in Figure 3. For further detail see https://www.skolaforrit.is/.

Lestur er leikur

Collection of six different games training phonological awareness. Among tasks are listening to words and identifying sounds, followed by pictures that represent that sound or not. The student is then supposed to tap on the pictures showing objects whose names contain that sound. For illustration see panel g) in Figure 3. For further detail see https://vefir.mms.is/lestur_er_leikur/.

Ritum rétt

A spelling game. The student chooses what spelling rule they want to work on. In the assignment the student is presented with a text with blanks that they need to fill in. For illustration see panel h) in Figure 3. For further detail see https://vefir.mms.is/ritumrett/index.htm.

2.3 Dependent measures

Word decoding task

The word decoding task, orðleysulestur, is a standardized word decoding assessment for children attending grades 3 and 4 (Menntamálastofnun, 2016). The task consists of a total of 40 pronounceable non-words (e.g., móf, dæku, gito). Performance is measured based on how many words a child reads correctly in one minute. The words are presented in two 20-word columns, the second column consisting of longer and more difficult words than the first one. To allow for equivalent pre- and post-test lists, we used an ABBA assignment to create two equally challenging groups of words, group A and B. Thus, the measurement of performance in each test became the number of these 20 that a child read correctly in 30 seconds. All the children completed the pre-test individually with the researcher. In the post-test 13 children worked individually with their class teacher, 3 children with their parents at home, and one with the researcher via video conferencing.

Reading comprehension task

The reading comprehension task, Orðarún, is also a standardized reading comprehension assessment for children in grade 3 (Birnisdóttir, Eggertsdóttir & Björnsdóttir, 2011a). It consists of two texts with ten comprehension questions following each text. The children completed one text before the intervention, text A, and the other, text B, after the intervention. The children finished the pre- test in a group of 8 with the researcher but in the post-test most of the children (13 out of 16) finished the test together in a small group of 5 to 6 children at school with the assistance of their class teacher. Three children finished the test at home with the assistance from their parents and one of them through video conferencing with the researcher. Performance was assessed as the number of correct responses produced to the comprehension questions (out of ten).

Working memory tasks

Two working memory tasks that assess different aspects of working memory were used.

Visuo-spatial working memory task

Based on a tapping test presented by Corsi (1972), the task demonstrated a bee flying between various trees. The child had to remember the order in which a bee lands on the trees, so that the farmer will know in which order the trees were pollinated and thus when to harvest his or her fruit. Performance was assessed as the total number of correct responses the child made across sequences of lengths varying from 2 to 5. There were two trials at each sequence length, meaning that the maximum possible score is 28 (i.e., 2+2+3+3+…+5+5). Feedback is provided in the form of the transformation the selected trees undertake when tapped: To a tree full of apples when correct, and otherwise to a tree filled with blossoms. Figure 4 demonstrates this task.

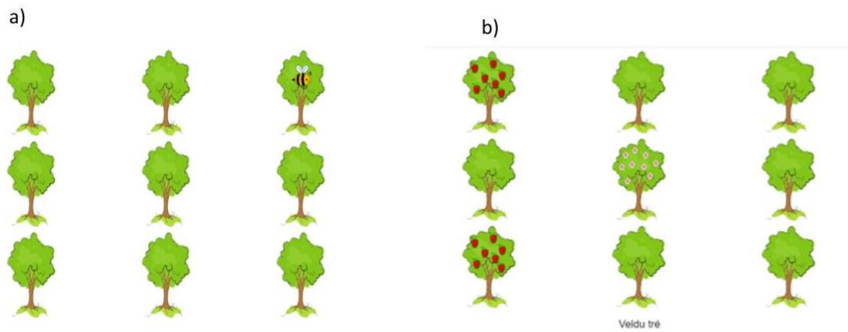

Figure 4 Screenshots from visuo-spatial working memory task. Panel a) shows the presentation of a trial, the bee flying between the trees and panel b) shows the answer, the student's response to where they think the bee went

Visual working memory - Delayed estimation

This task was based on the delayed estimation task first presented by Wilkin and Ma (2004). The child was asked to collect certain colours of sweets from the sweet shop by customers and had to remember which colours to select. They could choose from a selection of 90 different colours, arranged at 4-degree intervals around a quasi-equiluminant circular slice from a CIEL*a*b* colour space. Performance was assessed as the discrepancy in colour space (in degrees) between the correct sweet colour, and the colour of the sweet the child selected. The children used tablets and finished the pre-tests in groups of 8 children but in the post-tests 14 out of 16 children completed the tests in a small group of 5 to 6 children with their class teacher. Two children finished the tests at home using tablets with the assistance from their parents. Figure 5 demonstrates this task.

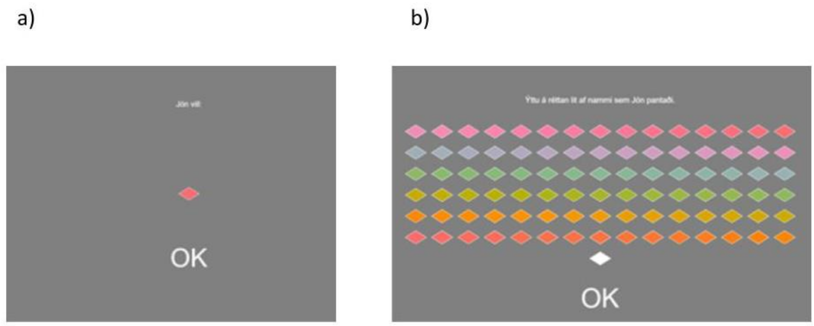

Figure 5 Screenshots from the visual working memory task. Panel a) shows the presentation of the colour the student needs to remember later from a range of colours. Panel b) shows the range the student needs to choose his answer from

Attention task

Attentional performance was assessed using a novel visual search task. The child was presented with a pre-specified soccer jumper (Fram, the children's local team) and then presented with a visual array made up of jumpers from Fram and another team with a similar design (Stjarnan, a rival team) on a soccer pitch. The child was then asked to identify the "free" (i.e., unmarked) Fram jumper as quickly as possible, by tapping on it. Response time (i.e., time taken to identify and tap on the free jumper) was the key measure of performance. The children finished the pre-tests together in a group of 8 children but in the post-tests 14 out of 16 children finished the test in a small group of 5 to 6 children with their class teacher and two finished the test at home with the assistance of their parents. Figure 6 demonstrates this task.

Figure 6 Screenshot from the attention task showing the range of jerseys. The student needs to tap on the "free" Fram jersey (shown here in the upper right corner)

Standardized tests are aimed to increase test consistency. The standardized sample in the reading comprehension test for grade 3 is based on a total of 644 grade 3 students for text 1 and 642 grade 3 students for text 2. The students answered a mean of 15 out of 20 total questions correctly, standard deviation was 4,2 and reliability was good (**α** = 0.82; Birnisdóttir, Eggertsdóttir & Björnsdóttir, 2011b, p. 8). The word decoding test is based on a standardized sample of students from 29 schools that participated in the submission of the tests in January, May and September 2016 (Skúlason, 2019). Dividing the word decoding and reading comprehension into two equally challenging subsets was designed to equalise difficulty across the pre- and post-tests. The attention task was a modification of well-known measures of visual attention (Wolfe, 2010), and the working memory tasks were analogously based on common working memory tasks (Wilken & Ma, 2004; Corsi, 1972). The working memory tests, and the attention tests were created using PsychoPy and PsychoJS (Peirce et al., 2019) and hosted on pavlovia.org.

2.4 Procedure

The research used a single-blind, intervention design with pre- and post-measurements of dependent variables before and after the intervention. Figure 7 demonstrates the timeline of the study. The independent variable was the type of intervention tasks the groups received: either working memory training or playing educational games on tablets, completed between the pre- and post-tests. When children had successfully been assigned to the two groups, pre-tests of dependent variables took place. We investigated the effects of working memory training on performance on five tasks: 1) a word decoding task, 2) a reading comprehension task, 3) working memory task -visuo-spatial working memory, 4) working memory task - visual working memory and 5) an attention task. The reading comprehension test, attention test, and working memory tests could be simultaneously completed by all the children, but the word decoding test needed to be completed one-on-one. The researcher who administered the tasks worked with two groups of 8 children at a time, each consisting of 4 students from the intervention group and 4 from the active control group. By ensuring that each group comprised an equal number of children from each condition, we intended to obviate the possibility that nuisance variables (e.g., the energy level of the researcher at a particular time) would be confounded with group allocation. After the intervention period finished data were collected with post-tests of dependent variables. Our pre-registered method involved the first author (G.G.) supervising the pre- and post-tests that the children could finish individually but simultaneously. The decoding test needed one-on-one assessment, so was completed non-simultaneously. This procedure was followed in the pre-tests, but because of circumstances relating to the COVID-19 pandemic, we were forced to alter this for the post tests. During the time when the post tests were to be conducted (March-April 2020), students' school attendance was disrupted, with some staying at home, some being quarantined, and others coming to school every other day. Further, G.G. was no longer allowed to meet the children from grade 3 owing to restrictions on interactions between school staff and different groups of students. The post tests were therefore completed with assistance from the class teacher in most cases, from parents in some cases, and through video conferencing in the remaining cases.

Our pre-registered method assumed that children (n=8) in the intervention group would finish a total of 25-30 CWMT training blocks, on average one training block per day, four days of the week for 5-6 weeks. We originally intended both children in the intervention group and the control group to complete around 25 days of the appropriate intervention tasks. However, the advent of the COVID-19 epidemic, along with more minor factors such as student illnesses, prevented us from successfully accomplishing this aim. Despite the various complications and restrictions, four children in the intervention group finished 18 training blocks, one child 17 training blocks, one child 15 training blocks and two children finished 14 training blocks. The children finished 8 to 10 different training tasks in these blocks and attended 11-16 training days. The attendance of the children in the control group was very similar, involving 9-16 training days instead of 25 originally planned. The children in the control group worked with one to three games each day they attended.

All children in the both groups worked with tablets and each child received headphones in order to minimize distraction for other children in the room. Children in the active control group worked on computer games that primarily trained phonological awareness and not memory-based games. However, the games that trained phonological awareness were quite homogeneous and became laborious for the control students. Therefore, during the intervention phase we decided to also include novel interactive games (e.g., math and music games) to try to match the engagement levels of children in both groups. Neither the children nor their parents were aware of the condition to which they were assigned, but in order to execute the intervention the researcher had to know to which group the child belonged. Therefore, the research used a single-blind design.

The research was conducted in accordance with the Declaration of Helsinki, and no identifying data were collected. Both the participating children and their parents provided informed consent and were informed that either the parents or the children themselves were allowed and able to terminate the children's participation at any given point in the research process.

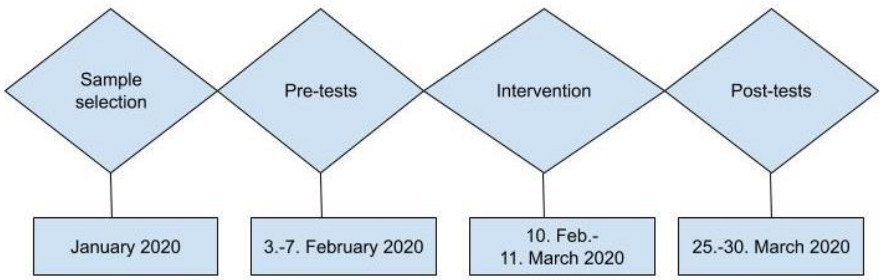

Figure 7 Timeline of the study

2.5 Data analysis

Data from pre- and post-tests of dependent variables were collected, and the means and standard deviations calculated to provide descriptive statistics. In our inferential analyses we used a Bayesian approach which we thought had two advantages. First, by using Bayes factors, which provide a measure of the relative likelihood of different models, it was possible to gather evidence in favour of the null hypothesis, which frequentist NHST analysis does not easily provide. In the case of the current study it is of practical and theoretical interest if the intervention does not have an impact. Second, using a frequentist NHST approach, if our p-value criterion is not exceeded (i.e., we end up with $p > .05$) all we can say is that we did not find a significant effect. By contrast, a Bayesian approach allows us to quantify the evidence in favour of or against an effect irrespective of how weak that evidence is. This point is particularly salient given the small scale of the study. Our data will therefore tell us something about the relative likelihood of the null and alternative models, even if they do not allow for decisive inference.

We conducted all analyses using the R package brms (Bürkner, 2018). All analyses involved two factors: Group (control vs. intervention) and time (pre- vs. post-training), and also included random intercepts for each participant. We calculated Bayes factors to assess all effects, using the bridgesampling package (Gronau, Singmann & Wagenmakers, 2020). Bayes factors (BFs) > 1 indicate evidence in favour of a model/effect, whereas values < 1 indicate evidence against a model/effect. For instance, a BF of 3 in favour of model A over model B indicates that model A is 3 times more likely than model B given the data; and a BF of 0.33 in the same comparison indicates that model B is 3 times more likely.

We compared four different models to a null model[1]. This null model was the most basic model, containing no effects of either group or session but instead assuming a single intercept, with participants randomly varying from one another in an unsystematic way. In this model all conditions are considered equivalent, so this should be the best model in cases where neither group nor session (nor their interaction) have an effect on the student's performance. Second, the session model contains only a main effect of the session. If performance were equivalent across groups, but there were practice effects from pre- to post-test (or equivalent training effects across both groups), we would expect this model to be best. Third, the group model contained only a main effect of the group. The model should be preferred in cases where the intervention group performs better than the control group (or vice versa), but this difference does not change across sessions, and there were no practice effects. Fourth, the main model contained both the main effects of group and session, but no interaction. This is the model we would expect to be superior if the groups differed from one another, and there was an effect of session, but the training did not differentially affect the groups. Finally, in the full model we included both the main effects of the group (i.e., control vs. intervention) and session (i.e., pre-test vs. post-test) and their interaction. This is the model we would expect to be superior if the groups differed from one another, there was an effect of session, and the training did differentially affect the groups.

[1] In addition to the effects specified in this paragraph, all models contained a random effect of participant.

To assess the presence/absence of an interaction, we compared the full to the main model.

For the word decoding, reading comprehension, and spatial WM tasks, we fitted binomial models to the data, since each task provided a certain number of successful trials or responses as its outcome. Thus, the effects specified above were used to predict the probability parameter of a binomial distribution. Putting this in a simpler way for the word decoding the students had to read nonsense words for 30 seconds and try to get as many correct as possible in that time. For the reading comprehension the student had to read a text, followed by ten questions and try to get as many of them right as possible. For the spatial WM task, the student had to click on the flowers in the right order a bee landed on and try to get as many correct out of 28 trials. For the visual search task, which uses single-choice response times as its outcome, we initially planned to fit an ex-Gaussian model, which is appropriate for a single-choice response time task (Matzke & Wagenmakers, 2009). However, we were unable to get the more complex ex-Gaussian models (e.g., the full model) to converge, and thus eventually used shifted log-normal models instead. Thus, the effects specified above were used to predict the mean and standard deviation of the distribution, as well as the shift parameter. Finally, for the visual WM task, we fitted a Von Mises model, with κ (i.e., precision) as the key parameter predicted (i.e., we assumed unbiased responding).

Because we were unsure what size effects---if any---to expect, we used relatively uninformative priors in all models, with the default link functions specified in brms. These are displayed in table 1.

Table 1 Priors with the default link functions specified in brms

Task	**Parameter**	**Prior**
Visual working memory	κ - intercept	Normal(5, 0.8)
	κ - effects	Normal(0, 1)
Spatial working memory	*p* - intercept	Student’s *t*(0, 10)
	p - effects	Normal(0, 1)
Decoding	*p* - intercept	Student’s *t*(0, 10)
	p - effects	Normal(0, 1)
Reading comprehension	*p* - intercept	Student’s *t*(0, 10)
	p - effects	Normal(0, 1)
Visual search	μ - intercept	Normal(0, 5)
	μ - effects	Normal(0, 1)
	τ - intercept	Normal(0, 10)
	τ - effects	Normal(0, 5)
	σ - intercept	Normal(0, 10)

All data and analysis scripts are available on the Open Science Framework at <https://osf.io/bpf83/?view_only=3d41a8b0770e464483a564985f5c53d2>.

3. Results

Descriptive statistics for all tasks are presented in Table 2. We present and discuss the analyses of each task sequentially.

Table 2 Descriptive statistics for all tasks

	Mean				stdv.			
Task	**C- S1**	**C-S2**	**I- S1**	**I- S2**	**C- S1**	**C-S2**	**I- S1**	**I- S2**
*Decoding	17.25	17.75	15.63	14.75	2.19	1.67	3.93	4.62
*Reading comprehension	7.63	6.88	6.00	6.63	2.33	2.53	2.83	1.51
*Visuo-spatial WM/simple spatial span	14.38	21.87	16.13	21.38	8.40	5.19	7.54	7.52
**Visual WM/delayed est.	16.35	19.35	28.05	19.35	5.73	11.69	20.39	13.14
***Attention/ visual search	5.16	3.16	5.47	3.476	2.50	0.754	1.46	1.05

C - S1: Control group session 1, C - S2: Control group session 2, I - S1: Intervention group session 1, I - S2: Intervention group session 2
* group mean of correct answers out subset, ** group mean absolute deviation from correct answer, *** group mean response time

3.1 Decoding task

Figure 8 shows the participant results and group means for the decoding task. Participants performed equivalently across the two groups and performance changed minimally from the first to the second session. As such, the null model provided the best account of the data (BF for all other models < .9 by comparison). Thus, our data suggest that working memory training does not have an impact on decoding ability. Furthermore, comparing the full model to the main model produces a BF= 0.78, indicating evidence against the presence of an interaction. This is inconsistent with what would be expected if training benefited decoding performance.

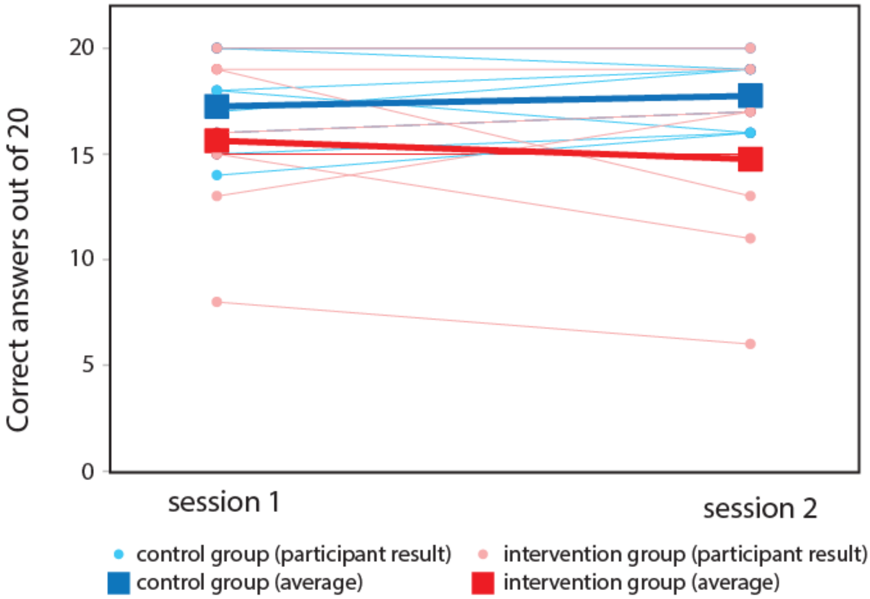

Figure 8 Group means and individual participants' data from the decoding task

3.2 Reading comprehension task

Figure 9 shows the participant results and group means for the reading comprehension. In this task participants also performed equivalently across the two groups and performance changed minimally from the first to the second session. Though the intervention group showed a numerical improvement in performance across sessions, the null model provided the best account of the data (BF for all other models < .7 by comparison). A comparison between the full model and the main model showed evidence against the effect of interaction (BF= 0.84).

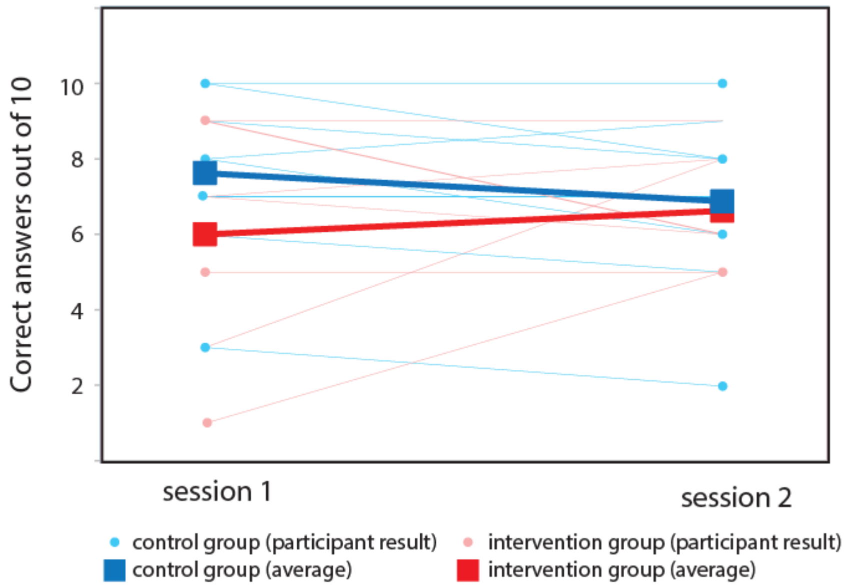

Figure 9 Participant results and group means for the reading comprehension task

3.3 Visuo-spatial working memory task

Figure 10 shows the participants results and group means for the visuo-spatial working memory test. Children who received WM training performed no better on the visuo-spatial working memory task than those in the control group. Both groups, however, performed better on the post-test than the pre-test. As such, the best model contained a main effect of session (BF=1.93 relative to the null model), indicating that this improvement was equivalent across the two groups. A comparison between the full model and the main model showed evidence against an interaction (BF=0.355).

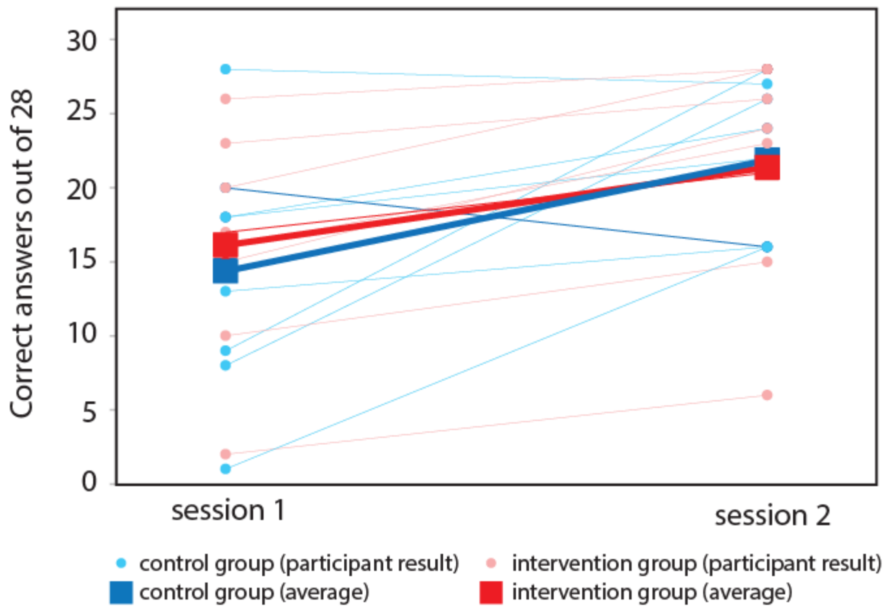

Figure 10 Participant results and group means for the visuo-spatial working memory task

3.4 Visual working memory task

Performance on the visual WM task is presented in Figure 11. The figure presents absolute deviation from the right answer (i.e., the colour presented originally). Thus, the higher the value, the greater the error.

The change in responses from session 1 to session 2 of the children in the intervention group was greater than of those in the control group, suggesting an effect of working memory training on the precision of the students' visual memory. As such, the full model provided the best account of the data (BF= 2.5 relative to the null model). Naturally, the full model was also superior to the main model (BF=7.64). Thus, our data provide evidence in favour of an effect of working memory training on the visual working memory task.

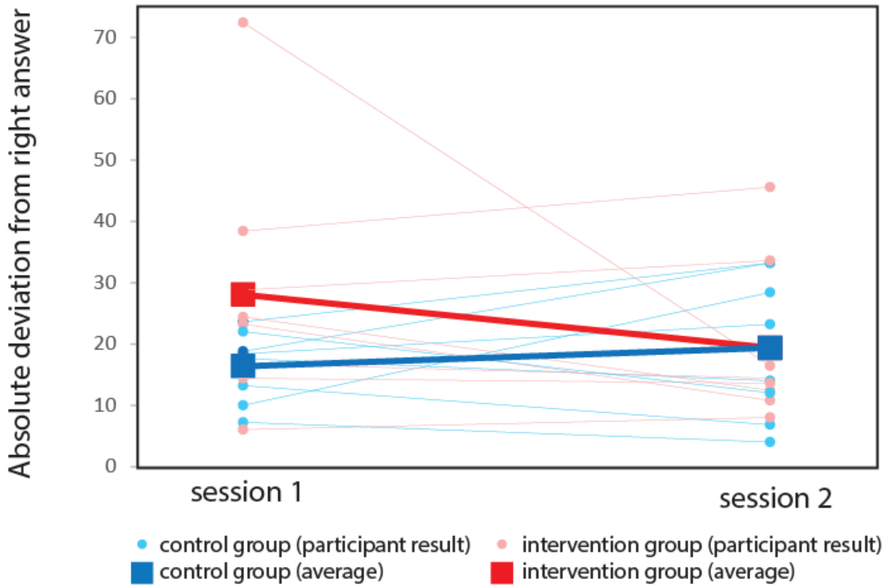

Figure 11 Participant results and group means of absolute deviation for the visual working memory task

3.5 Attention task

Performance on the visual search task measuring attention is presented in Figure 12. The figure presents participant response time, thus the lower the value the faster the student was to complete the task. The best model here was the one with only main effect of session (BF=2602804 relative to the null model). Students from both groups, control and intervention, improved from the pre-tests to the post tests but the improvement was almost exactly identical across groups. A comparison between the full and main models provided evidence against the presence of an interaction (BF=.0077), suggesting that WM training did not affect performance.

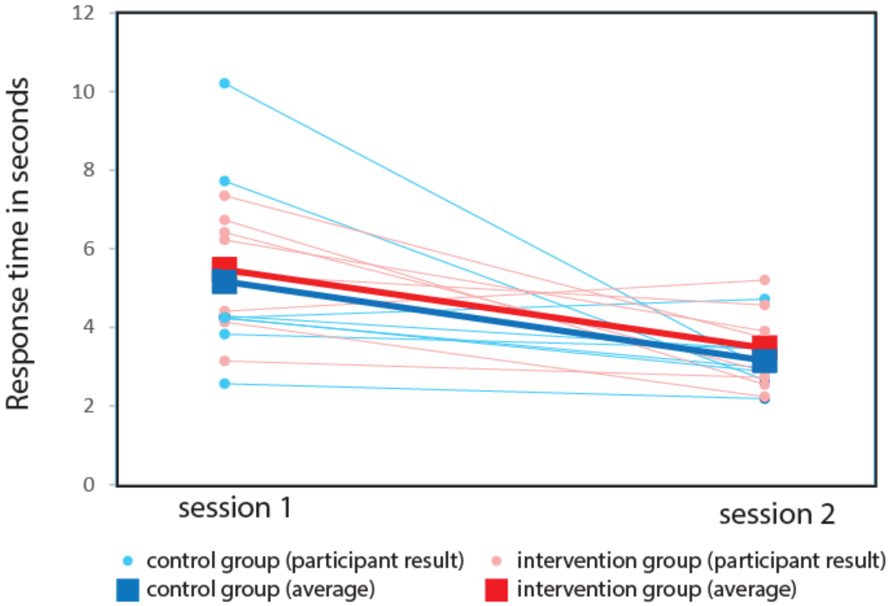

Figure 12 Participant results and group means of response time for the visual search task

4. Discussion

In the study reported here, we aimed to determine whether WM training would only be beneficial to near transfer tasks (e.g., similar WM tasks) or if it would benefit far transfer tasks like word decoding, reading comprehension, and visual attention. We assessed the effects of training on five tasks: Two working memory tasks---visuo-spatial working memory (simple spatial span) and visual working memory (delayed estimation)---, one visual attention task, a word decoding task, and a reading comprehension task. We hypothesised that WM training would have positive effects on near transfer tasks like the WM tasks, as well as on far transfer tasks like reading comprehension and the attention task (visual search) but would not affect word decoding ability.

Our data were broadly inconsistent with these hypotheses. They showed that after 14-18 training blocks of Cogmed working memory training students improved on one near transfer task--- the visual working memory task---but not on the other--- the visuo-spatial working memory task. Further, our data provided weak evidence against the effectiveness of training on far transfer tasks like word decoding, reading comprehension, and visual search. These results are mostly consistent with the findings of Simons et al. (2016) listed earlier, namely that close relations have been found between WM training and performance improvement on the trained task, less evidence that interventions improve performance on closely related tasks (i.e., near transfer), and minimal evidence that training enhances performance on distantly related tasks (i.e., far transfer) or that training improves everyday cognitive performance. We next discuss our findings concerning the different tasks in turn.

4.1 The Working Memory tasks

Our pre-registered sub-hypotheses were that training would have positive effects on both the working memory tasks, so it is unclear why positive effects were found in the visual WM task and not the visuo-spatial WM task. The latter task was much more similar to many tasks included in the Cogmed WM program (especially the space whack, asteroids and data room) than the former task, so if nearness of transfer is a key variable in determining the effectiveness of WM training, one might expect the opposite pattern. One possibility might be that the children simply put more effort in solving the visual WM task than the visuo-spatial WM task. During the pre-tests, the first author (who was administering them) noticed that several of the students mentioned that they thought the visual WM task was the hardest one. When completing the post-tests, the children may thus have been better prepared for the difficulty of the task, and aware that they needed to concentrate to get a good outcome. Looking at the individual data, it also appears that one child in particular who performed poorly in the pre-test did quite well in the post-test. Because this child was in the intervention group, this makes the average for that group substantially better after training. Thus, the change could simply be a result of one student's substantially improved post-test performance---perhaps as a result of their not understanding the task well to begin with. Excluding this child's data from the analysis leads to a substantially different outcome, with the null model becoming the superior one and the group model relative to the null model being second best (BF=0.52). This lends credence to the idea that the positive effects obtained in the full analysis may be specious.

4.2 The decoding task

We hypothesised that we would not find positive effects of WM training on decoding ability, consistent with the results of Foy and Mann (2014). The data were consistent with this expectation, and additionally showed that the control group had a higher mean of correct responses in session 2 relative to their performance in session 1 whereas the mean of correct responses decreased between sessions with the intervention group. Given that the control group mainly worked with computer games that trained decoding ability, this pattern may indicate that regular, monitored computer games training decoding ability can have positive effects in educational outcomes. This is not surprising since researchers (e.g., Ehri & Snowling, 2004; Eklund & Lyytinen, 2006; Otaiba, Kosanovich & Torgesen, 2012; Spear-Swerling, 2015; Torppa, Poikkeus, Laakso; Walpole & Mckenna, 2007) have demonstrated positive effects from training different aspects of phonological awareness---including decoding ability---for the reading process. On the surface, this could be viewed as indicating that the lack of evidence for training effects was simply a result of the control group's direct practice at decoding during the intervention. However, the working memory training clearly did not have positive effects on decoding ability for the intervention group since their score did not even improve numerically from session 1 to session 2.

4.3 The reading comprehension task

We did not find any effect of WM training on reading comprehension, with the null model providing the best account of the data. This is inconsistent with the findings of Dahlin (2011), and the related hypothesis we derived from this past research. Interpreted generously, our data showed a very slight improvement with WM training, such that the mean for the correct responses increased for the intervention group between sessions where the opposite happened with the control group. What might account for the discrepant results of our study and Dahlin's findings? A relevant difference between the two studies lies in the sample. In the current study our sample was selected to represent the typically developing child in the third grade, being educated in ordinary school settings. All students that were receiving special education were hence excluded from the sample. Dahlin's study, on the contrary, was targeted only to children receiving special education who were diagnosed as having attention deficits and general learning problems. They were being educated in small groups in ordinary school settings. Though it is also possible that the difference may simply be an artefact of imprecise effect estimates obtained from our small sample, it may be worth investigating the possibility that special education status interacts with training effects on reading comprehension.

4.4 The attention task

Findings from the attention task (visual search) were inconsistent with our hypothesis of positive effects of WM training on far transfer tasks like controlled attention. Though there were substantial improvements from the pre- to the post-test, both groups' scores improved almost equally between sessions. Despite the broad consensus among researchers that working memory is related to attention the results from the current study emphasize the complexity of just how attention is related to working memory. It is possible that the type of attention trained in the Cogmed WM training tasks is somehow different to that required in a visual search task, in which case the training would not be expected to transfer to search task performance. Alternatively, the Cogmed WM training may simply not improve attentional performance; though that would be inconsistent with the findings of Klingberg et al., (2005) and of Holmes et al., (2010) who found substantial evidence in their research for improvements of Cogmed WM training in visuo-spatial short-term memory, reductions in parent ratings of inattentive behaviours and verbal and visuo-spatial WM. Holmes et al., (2010) point out that the training may not enhance working memory capacity but rather guide the student towards successful WM strategies that compensate for weaknesses in basic processes or of voluntary control of attention. In the present study voluntary control of attention might not have been a problem since the task itself, finding the free Fram soccer jersey, was captivating enough for the children: they enjoyed completing it.

4.5 Practical Implications

There are several potential reasons why the Cogmed Working Memory Training (CWMT) did not improve performance in the tasks mentioned. First, it may simply be the case that the training contained in the program does not improve performance in non-trained tasks. However, this would be inconsistent with some aspects of our findings, such as the evidence for a positive effect of training on visual working memory, as well as with prior research showing consistent near-transfer effects (e.g., Simons et al., 2016).

Second, the children in the intervention program may not have finished enough training blocks. The standardized model proposed by Pearson, assuming that participants would work 4 days a week for 25 minutes each time, was 40 training blocks, but due to time constraints and the impact of the COVID outbreak we were only able to have students complete 14-18 blocks of training in the current study. Completing the standardized model of 40 training blocks takes up to ten weeks, which represents a substantial investment if the intervention is to take place in an educational setting. This highlights one of the practical concerns about using Cogmed and other similar working memory training programmes: Students' time invested in CWMT can also be seen as time lost from the classroom, as others have noted (e.g., Roberts et. al., 2016). This lack of benefit of the training must also be considered against the price of the program ($1000 licence) and the loss of 14-18 hours of usual classroom teaching for each child and the related opportunity costs (e.g., for other remediation that could have been offered instead), as Roberts et al. (2016) highlighted. Pearson's Claims and Evidence paper about CWMT (Pearson, 2019) mentions that the training does and will not replace education, but should rather be seen as an add on that can potentially aid learning in an educational setting. Furthermore, it is mentioned that if Cogmed is used within a school setting it is important to plan the implementation to interfere as little as possible with formal teaching (Pearson, 2019, p.27). Given that many school-age children are extremely busy with a variety of leisure activities, sports, and hobbies after school hours, CWMT would be in direct competition with those activities. We have personally witnessed the difficulties many parents have in getting their children to simply sit down to read for 10-15 minutes each day, which raises questions about the viability of an 8-9-year-old child spending four days a week for 25 minutes across 10 weeks (standardized Cogmed protocol) after school to do working memory exercises. Thus, completing the training within a school setting improves the odds of successful implementation (pandemics aside). On the other hand, the children in the intervention group mostly seemed to enjoy the exercises---and particularly the robo racing rewarding system that they were allowed to play at the end of each completed training block---suggesting that its completion may not be viewed as a chore, but instead by at least some as a desirable activity. Nonetheless, our data add to suggestions that, instead of trying to improve underlying cognitive deficits, like deficits in WM, the focus should rather be on teaching relevant academic skills, in this case those concerning reading and spelling (Elliott & Grigorenko, 2014, p. 62-63).

4.6 Future directions

Since the current study did not focus on students with learning disabilities it is not possible to make assumptions about CWMT as a preventive measure for potential learning disabilities, and it may be worthwhile to investigate this issue further. The small sample size of the current study is a limitation. Larger studies including children with learning disabilities or diagnosed as having attention deficits may be beneficial to advance our understanding of whether and how working memory training can support learning.

5. Conclusions

In this study our results demonstrated evidence of the effect of working memory training only in one out of two near transfer tasks, visual working memory; and that positive effect could be seen as illusory due to the unusual performance of one child in the intervention group. Evidence against an effect of training was found in a visuo-spatial working memory task, classified as the other near transfer task, and all the far transfer tasks, namely word decoding, reading comprehension, and visual search. Given the high cost of the program and the loss of usual classroom teaching during Cogmed Working Memory Training (CWMT), our findings can be viewed as providing evidence against implementing CWMT as an intervention for typically developing 9-year olds in Iceland. However, this recommendation must be tempered by the fact that a number of practical considerations prevented the training programme from being implemented fully.

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Fylgiskjöl

Fylgiskjal 1 Kynningarbréf um rannsóknina

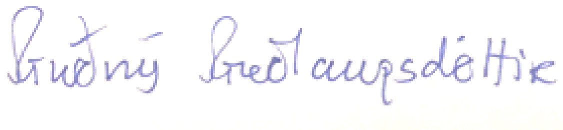
Ágætu foreldrar og forráðamenn,

Undirrituð, sérkennari í Sæmundarskóla, vinnur að lokaritgerð til mastersgráðu í sérkennslufræðum við Háskólann á Akureyri. Lokaverkefnið verður rannsókn á áhrifum þjálfunar á vinnsluminni á umskráningarfærni (tengja staf við hljóð), lesskilning, athygli og vinnsluminnið sjálft. Þjálfunin verður með tölvuforriti sem nefnist Cogmed og er í formi tölvuleikja. Gert er ráð fyrir að vinna með tvo hópa barna, annar hópurinn fær þjálfun á vinnsluminni en hinn hópurinn ekki. Fyrir og eftir íhlutun verða fjórar breytur mældar, 1) umskráningarfærni þar sem bullorð eru lesin á ákveðnum tíma, 2) lesskilningur þar sem lesinn er texti og spurningum svarað, 3) tvær ólíkar athyglismælingar með aðstoð tölvu og 4) tvær mælingar á vinnsluminni einnig unnið í gegnum tölvu.

Miðað er við að íhlutun fari fram á vorönn, líklega í febrúar og/eða marsmánuði, í 5-6 vikur, 4 daga vikunnar í u.þ.b. 30 mín í senn. Viðmiðunarhópurinn sem ekki fær þjálfun á vinnsluminni mun vinna með námsleiki í spjaldtölvu á sama tíma og tilraunahópurinn er í vinnsluminnisþjálfun. Báðir hópar munu vinna sín verkefni á skólatíma, fjarri skólastofunni, undir stjórn rannsakanda. Til að auka réttmæti og áreiðanleika rannsóknarinnar, þá geta hvorki, börnin, foreldrar þeirra, né umsjónarkennara fengið að vita hvorum hópnum barnið tilheyrir. Niðurstöður mælinga, sem verða ópersónurekjanlegar, verða dregnar saman og birtar í mastersritgerð. Þeir sem munu hafa aðgang að þeim gögnum sem verður aflað á meðan á rannsókn stendur verða rannsakandi og tveir leiðbeinendur sem báðir starfa sem lektorar við sálfræðideild Háskólans á Akureyri.

Í samráði við skólastjórnendur Sæmundarskóla og umsjónarkennara 3. bekkjar hefur verið ákveðið að fá úrtak nemenda í 3. bekk til að taka þátt í rannsókninni. Því leita ég hér eftir samþykki þínu sem foreldri/forráðamaður barns í 3. bekk, sem uppfyllir úrtökuskilyrði, að leyfa barninu þínu að taka þátt í þessari rannsókn. Til að gefa til kynna upplýst samþykki eru foreldrar/forráðamenn beðnir um að skila undirskrift sinni aftan á þessu blaði eigi síðar en 21. janúar (foreldraviðtalsdagur í Sæmundarskóla). Aðeins eitt foreldri eða forráðamaður þarf að skila sínu samþykki. Barni þínu frjálst að hætta þátttöku hvenær sem er á ferlinu. Rannsakandi er fús til að svara frekari spurningum út í rannsóknina í gegnum tölvupóst: gudny.gudlaugsdottir@rvkskolar.is.

Með von um góðar undirtektir,



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Guðný Guðlaugsdóttir

Fylgiskjal 2 Upplýst samþykki fyrir þátttöku í rannsókn

UPPLÝST SAMÞYKKI FYRIR ÞÁTTTÖKU Í RANNSÓKN

Ég staðfesti hér með undirskrift minni að ég hef lesið upplýsingarnar um rannsóknina sem mér voru afhentar og hef fengið tækifæri til að spyrja rannsakendur spurninga um rannsóknina og fengið fullnægjandi svör og útskýringar á atriðum sem mér voru óljós.

Ég samþykki að leyfa barninu mína að taka þátt í rannsókninni af fúsum og frjálsum vilja. Ég er upplýst(ur) um að barnið getur hætt þátttöku hvenær sem er, án þess að þurfa að gefa á því skýringu, og að það mun ekki hafa neinar neikvæðar afleiðingar fyrir það né mig,.

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Dagsetning

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Nafn þátttakanda í rannsókn (barn)

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Nafn foreldri/forráðamanns

Undirrituð, sérkennari í Sæmundarskóla og mastersnemi í sérkennslufræðum við Háskólann á Akureyri, staðfestir hér með að hafa veitt upplýsingar um eðli og tilgang rannsóknarinnar, í samræmi við lög og reglur um vísindarannsóknir.

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Guðný Guðlaugsdóttir