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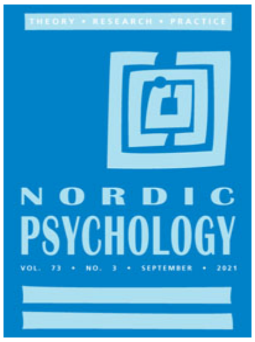
Published in:
Nordic Psychology (Online)

DOI (link to publication from Publisher):
10.1080/19012276.2020.1856001

Publication date:
2021

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Knudsen, H. B. S., & De Lopez, K. M. J. (2021). Face-to-face working memory training does not enhance children’s reading comprehension - a pilot study with Danish children. *Nordic Psychology (Online)*, *73*(3), 211-225. Advance online publication. https://doi.org/10.1080/19012276.2020.1856001



Nordic Psychology

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rnpy20

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To cite this article: Hanne B. Søndergaard Knudsen & Kristine M. Jensen de López (2021) Face-to-face workin g memory training does not enhance children's reading comprehension - a pilot study with Danish children[1], Nordic Psychology, 73:3, 211-225, DOI: 10.1080/19012276.2020.1856001

To link to this article: https://doi.org/10.1080/19012276.2020.1856001

Nordic Psychology, 2021
Vol. 73, No. 3, 211–225, https://doi.org/10.1080/19012276.2020.1856001 ARTICLE

Face-to-face working memory training does not enhance children's reading comprehension - a pilot study with Danish children[1]

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Abstract

The argument that Working Memory (WM) is especially important for reading comprehension has been supported in previous research. The aim of this study was to test a non-computerized WM training method to improve children's reading comprehension in a longitudinal design. 38 Danish children in 3rd and 4th grade (M = 112.9 months, SD = 7.90 months) were divided into a training group (*N* = 18) and a control group (*N* = 20). Assessments of sentence reading comprehension and WM were administered at pre- and post-test, half-year and one-year follow-up. Verbal WM and reading comprehension were not improved following training. Visuo-spatial WM improved at post-training, but the effect did not last into the one-year follow up. The role of WM in reading comprehension and the pedagogical implications for teaching are discussed.

Keywords: working memory, training, children

Introduction

Reading abilities are highly important for various life outcomes such as academic success (Hakkarainen et al., 2013), quality of life (Nydén et al., 2008), psychosocial functioning (Parhiala et al., 2015) and mental health (Willcutt et al., 2007). In recent years, there has been a growing interest in finding new ways of improving academic skills through cognitive training (for a meta-analysis see Melby-Lervåg & Hulme, 2013; Melby-Lervåg et al., 2016). However, so far, the results are contradictory. This study contributes to the debate by presenting results from a face-to-face Working Memory training study that aimed to improve reading comprehension abilities of Danish school children.

Working Memory (WM) comprise a system that allows the temporary storage and manipulation of information necessary for complex tasks (Baddeley, 2000). According to Baddeley and Hitch's original model, WM consists of a domain-general central executive responsible for the processing and manipulation of information, and two domain-specific

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[1] The study formed a part of the first author's PhD dissertation.

storage subsystems responsible for the retention of phonological and visuo-spatial information (Baddeley, 2000). The phonological and visuo-spatial storage systems are tapped in short-term memory tasks requiring the immediate recall of phonological or visuo-spatial material, respectively. For example, digit recall requires the immediate repetition of lists of spoken digits and is considered to place demands on phonological short-term memory. WM tasks require the processing of information by the central executive as well as the storage of material by the relevant storage subsystem, as exemplified by a verbal WM task requiring judgement of sentences while recalling final words (Daneman & Carpenter, 1980) or a visuo-spatial WM task requiring the identification of the odd shape in an array and recall of its location (Henry, 2001).

Reading comprehension – what supports it?

At a minimum, reading comprehension involves decoding of single words, and comprehension of decoded material. According to The Simple View of Reading (SVR), reading comprehension is determined by decoding and linguistic comprehension skills (e.g. syntactic parsing and compositional semantics) and their interaction (Hoover & Gough, 1990). Numerous studies have supported the SVR model with English-speaking children (Catts et al., 2006; Kendeou et al., 2014), and with Scandinavian alphabetic orthographies such as Norwegian (Høien-Tengesdal & Høien, 2012) and Swedish (Gustafson et al., 2013).

Other researchers point to a broader range of abilities needed for reading comprehension such as "attention, memory, critical analytic ability, inferencing, visualization ability", motivation and knowledge, e.g. vocabulary and linguistic knowledge (Snow, 2002, p. 13). It is important to stress that the role of WM in reading comprehension is not solely a question of static storage available for the reader, but also about how quickly relevant information is processed.

Furthermore, results from studies that investigate individual differences in reading comprehension suggest that a large range of domain-general abilities play direct or indirect roles in explaining differences between low and high-proficient readers. Specifically, the readers' abilities in reading and listening span tasks have been shown to correlate highly with reading comprehension (Daneman & Carpenter, 1980). Furthermore, WM capacity measured as reading span, but also as listening span is correlated with two specific active components of reading comprehension, namely the readers' ability to retrieve facts quickly from memory and the ability to compute pronominal references (understanding and keeping in memory what the reference of a pronoun is, while reading the text). Daneman and Carpenter (1980) argue that it is the quality, e.g. in terms of *processing efficiency and chunking* that can explain differences between poor and good readers. The reading comprehension task applied in the present study addressed *processing efficiency and chunking* in unrelated sentences that required the reader to judge whether they were correct or incorrect in relation to an illustration. The sentences gradually became longer and more complex, and also demanded the ability to involve the child's background knowledge in order to infer what was only mentioned indirectly.

Other authors have questioned the direct relevance of WM to reading comprehension, and point out that many other cognitive domain general and domain specific abilities equally play important roles in reading comprehension, e.g. within the Connectionist-based framework of MacDonald and Christiansen (2002), and the Structure Building Framework of Gernsbacher (1990). The direct role of cognitive abilities has to some extent been supported for Danish readers in our work showing the relationship between reading comprehension and cognitive flexibility in young children (Knudsen et al., 2018).

An additional and non-processing approach to understanding what supports reading comprehension is also addressed in the work of Snow who argues that because meaning must be actively constructed in reading a text, readers must hold a repertoire of abilities that support comprehension monitoring (Snow, 2002), and which include language experience, world knowledge and vocabulary. Results from a recent large study suggest that decoding and WM may be secondary in contributing to reading comprehension, whereas language experience may have a more direct role (Freed et al., 2017).

An important consideration when examining cognitive supports for reading comprehension is possible changes over development. As children acquire new knowledge, considerable cognitive effort is required (Baddeley, 2000). Once skills become automatic, however, the processing demands for executing those skills decrease. When applied to reading comprehension, it can be expected that the cognitive demands of word decoding will decrease as children gain expertise in single word reading (Gough & Tunmer, 1986).

Working memory training and reading comprehension

The argument that WM is especially important for reading comprehension has been supported in previous research (Cain et al., 2004; Carretti et al., 2009; Chrysochoou et al., 2011; Engel de Abreu & Gathercole, 2012; Gathercole & Pickering, 2000; Leong et al., 2008; Seigneuric & Ehrlich, 2005; Swanson & Jerman, 2007). Similarly, evidence from longitudinal studies suggests a predictive role of WM for later reading comprehension (Etmanskie et al., 2016; Franchis et al., 2017; Nevo & Bar-Kochva, 2015; Seigneuric & Ehrlich, 2005; Welsh et al., 2010).

Findings show that performance on both verbal and spatial WM tasks correlates with reading comprehension (*r* .33-.42 for spatial and *r* .28-.47 for verbal WM) (Kane et al., 2004, p. 201). Moreover, verbal and visuo-spatial span tasks were highly correlated, and shared 70-85% of variance, indicating that these tasks to some extent are measures of a domain general capacity (Kane et al., 2004, p. 208). The combination of domain specific and general factors contributing to reading comprehension was also found in a meta-analysis by Carretti et al. (2009) (for a discussion, see Knudsen & Jensen de López, 2018). However, it should be noted, that the interpretation of studies showing associations between WM and reading has also been questioned; for example, MacDonald and Christiansen (2002) argued that the observed relationship between verbal WM and linguistic tasks arises because such tasks are simply different measures of the same underlying language processing resource.

The evidence that WM supports reading has led to interest in the effect of WM training. However, results from existing training studies are inconclusive, and fraught with design issues. Some studies showing improvements in reading have not included an active control group (Dahlin, 2011; Egeland et al., 2013; Holmes & Gathercole, 2014; Loosli et al., 2012; Söderqvist & Nutley, 2015), and most findings have no follow-up measures. An exception is the study of Karbach et al. (2015), who showed that improvements in WM transferred to reading ability from pre- to post-test, but the training effect was no longer significant at three-month follow-up (for an overview of WM training studies, see Knudsen & Jensen de López, 2018). Other WM training studies have found an effect on WM measures, but not on reading (Chacko et al., 2014; Dunning et al., 2013; Gray et al., 2012; Hitchcock & Westwell, 2017; Holmes et al., 2009; Partanen et al., 2015; Rode et al., 2014; St. Clair Thompson et al., 2010; Studer-Luethi et al., 2016).

Importantly, some of the differences in research findings may be due to differences in children's age. In a review article, Wass et al. (2012, p. 360) conclude "that cognitive training applied to younger individuals tends to lead to significantly more widespread transfer of training effects". However, multiple review studies have reported that *computer* WM training results in short-term, task-specific improvements that do not generalize to other areas (Melby-Lervåg et al., 2016; Melby-Lervåg & Hulme, 2013; Rapport et al., 2013; Redick et al., 2015; Simons et al., 2016). The studies in the reviews targeting WM training all use a computerized drill approach in a game context.

Little is known about the effect of face-to-face training. One study applied a face-to-face WM training instead of computerized training with 5-8-year-old English-speaking children ($N = 36$) who received 18 sessions of 10 minutes' face-to-face training three times a week for 6 weeks (Henry et al. (2014). The training consisted of adaptive practice on a competing language processing task and an Odd-one-out task. At post-test, the trained group showed significantly larger gains compared to the control group on the two trained WM tasks and on two untrained tasks, as well as significantly higher reading comprehension scores compared to the control group at a 12-month follow-up.

However, reading comprehension was only measured at the follow-up, but not at the pre-test or post-test, so it was unclear whether the differences between the groups in reading comprehension had been present before the intervention started. Based on the findings in the Henry et al. (2014) study, we predicted that it would be possible to improve children's WM and thereby improve children's reading comprehension – thus obtaining both near and far effects through training. We followed a more stringent design allowing us to control for pre-test differences. Our study also addresses the lack of research on Danish school-age children's reading, given that most studies are with English-speaking groups, and we included older children that may have more automatized decoding skills.

Despite the 'real world conditions' in the current study, we also endeavoured to control for skills other than WM that could influence the study results by including direct measures of fluid (nonverbal) intelligence and language abilities. Recent research has shown that WM and fluid intelligence are linked in adults (e.g. Conway et al., 2002; Kane et al., 2005), and in children (Engle de Abreu et al., 2010). We also know that reading comprehension relies on language comprehension (Gough & Tunmer, 1986). Furthermore, we aimed to account for individual differences in these related skills to better understand the impact of our WM training.

The purpose of this study was to test a non-computerized face-to-face WM training method to improve Danish-speaking school-age children's reading comprehension in a longitudinal design. The basic content of the training was highly inspired by the WM training intervention used in the Henry et al. (2014) study, with the exception that our training period was reduced to four weeks compared to six weeks.

Method

Intervention

The training variables in our study consisted of two WM tasks, one verbal WM task, the Competing Language Processing Task (CLPT) (Daneman & Carpenter,1980), and one visuospatial WM task, the Odd-One-Out task. In the CLPT children were instructed to recall the sentence-final word in a series of statements after judging the truth-value of each statement. In the Odd-One-Out task children were first presented with horizontal arrays of three abstract figures and asked to identify the figure that differed from the others. They were then asked to recall the location of the figure on a blank response board.

The control group received equal one-to-one attention with the same trainers, but "did simpler versions of the tasks, requiring only the processing part of each task, with no requirement for memory storage" (Henry et al., 2014, p. 90). The sessions were the same length, ten minutes (five minutes per task) and the same training materials were used with both groups.

Each child's span level for both tasks was measured at pre-test and was the starting point for the first training session intervention. If two consecutive trials were answered correctly, e.g. at level 2 (where the child had to remember two items), the span level was increased by one for the next two trials to level 3, (where the child had to remember three items). If two consecutive trials were answered incorrectly e.g. at level 2, the span level for the next two trials was decreased by one to level 1, (where the child only had to remember a single item at a time), etc (Henry et al., 2014, p. 91).

A session started at the level, where the child stopped in the previous session. In that way, the starting point changed from session to session. The combination of items was always new in these training sessions, and different from the test versions. Although the children enjoyed the training, they became tired, and it was our judgement that the training could not have continued as long as recommended for computer training games (30-45 minutes).

Participants

The study included 24 third and 14 fourth grade children (16 females) from two classes of a main school in Denmark, ranging in age from 8 years 4 months to 10 years 8 months (M = 112.9 months, SD = 7.90 months). Recruitment was initiated through personal contact with the school principal. One hundred informed consent forms were sent out to parents through the teachers, and 39 children were given written permission from parents to participate; one child subsequently dropped out.

The sample was self-selected: the children who signed up for the study participated. 18 children were allocated to an experimental group (EG) and 20 children to an active control group (ACG). The children were at T1 assigned to the groups following a procedure that assured the two groups to be approximately equal in reading comprehension, language comprehension (measured with TROG-2) and nonverbal intelligence (measured with Matrix Reasoning) and with an equal distribution of gender and grade. The WM trainers were the first author, who is a licensed psychologist, and a master's student of psychology who had been trained by the first author. Each child met individually with their WM trainer in a quiet room at the child's school three times a week for a 10-minute training session.

The children were of middle socioeconomic status, based on parents' education levels. Due to procedural errors, children's absence from school for different reasons, or transfer to other schools, 36 children completed the sentence comprehension task at pre-test (T1, August, 2013), 36 at post-test (T2, October, 2013), 31 at half-year follow-up (T3, April 2014) and 34 at one-year follow-up (T4, January 2015).

Table 1. Tasks, training and timepoints

Timepoints	*WM*	*Reading comprehension*	*Other measures*
T1	Digit Span Back CLPT Odd-One-Out	Sentence comprehension	TROG-2 (language comprehension) Matrix Reasoning (nonverbal intelligence)
12 training sessions (4 weeks)	*Training versions of: CLPT & Odd-One-Out*		
T2	Digit Span Back CLPT Odd-One-Out	Sentence comprehension	
T3	Digit Span Back CLPT Odd-One-Out	Sentence comprehension	
T4	Digit Span Back CLPT Odd-One-Out	Sentence comprehension	

Design and materials

At T1, children were evaluated in two test sessions carried out on two days at the children's respective school during regular school hours. All tasks started with a practice phase in which task instructions were explained to the child. Measures completed in individual sessions included: Test for Reception of Grammar (TROG-2), Matrix Reasoning and WM tests (Digit span, CLPT and Odd One Out). Sentence comprehension was measured in a group setting. All Post-tests (T2, T3, T4) included the three WM tests and sentence comprehension. For an overview of the tasks, training and time points, see Table 1.

Tasks

Language comprehension: The Danish version of *TROG-2* (Bishop, 2010; Jensen de López & Knüppel, 2010) is a multiple-choice test, assessing comprehension of grammar and syntax. The test material consists of a stimulus book with four pictures for each task, and the child is instructed to point to the picture that corresponds to a sentence being read aloud. Responses are scored as correct or incorrect. The maximum possible raw score is 80.

Nonverbal intelligence: The Matrix Reasoning subtest from the *Wechsler Intelligence Scale for Children*, *WISC-IV* (Wechsler, 2010) required the selection of an item to complete a partially filled grid in a stimulus book. The score reported was the number of correct answers.

Working Memory. *The Digit Span Task* from the WISC-IV (Wechsler, 2010) was used to measure the children's verbal WM. We used the raw score on the items requiring backwards digit recall only. Reversing and recalling the order of items measure the processing and storage components of WM.

The Competing Language Processing task (CLPT) is a listening span test and was adapted into Danish from the original Gaulin and Campbell task (Gaulin & Campbell, 1994; Sundahl Olsen & Jensen de López, 2010). Children had to recall the sentence-final word in a series of statements after judging the truth-value of each statement. The task had five levels with two items per trial and with the number of sentences increasing from two to five for a total of 42 test items. All items were administered in this non-training version, making it possible to reach the maximum score. Span (the level with both items correct) was calculated and used as a starting point for the intervention sessions.

The Odd-One-Out task (Henry, 2001; London South Bank University, 2011) measured the children's visuo-spatial WM. Children were first presented with a horizontal row with three abstract figures and asked to identify the figure that differed from the others (the odd one out). They were then asked to recall the location of that figure on a new screen with a horizontal row with three blank boxes. The child then proceeded to the next level and was presented with two horizontal rows and now asked to identify and then recall two odd one out figures. The task consisted of a total of six levels, and each level had four trials. The child proceeded to a higher level if at least three out of four responses were correct, at any one level. The score was calculated as the number of correct trials out of a maximum possible 24 (4 × 6). Span (defined as the level with three or four trials correct, out of four possible) was calculated and used as a starting point for the intervention

Reading. The standardized Danish group test of sentence reading *Sætningslæseprøve 2* (Møller & Juul, 2012) was administered to all the children. This test was developed for use in 2nd to 5th grade. The children were presented with one coloured picture and four printed sentences and were asked to mark whether or not each sentence matched the picture. The sentences gradually became longer and more complex, and some sentences demanded the ability to involve children's background knowledge (Møller & Juul, 2012) for an example, see Juul, 2009. The score was the number of correct responses during an 8-minute sequence. Two children's scores on this measure were lost due to procedural errors.

Statistical analysis

Analysis were employed within SPSS, version 27. Data was inspected in order to remove outliers (defined as more than 3 SD from the mean) in each dependent variable; however, no outliers were identified. In the result section, descriptive statistics of all measures are initially presented, followed by effect size calculation (Hedges' *g*). In order to compare the two groups in the study (EG and ACG) at post time-points, we initially applied independent samples t-tests to check for differences between the groups at baseline. Next we applied a repeated measure mixed ANOVA to examine significant changes in sentence comprehension at post training, 2 (EG and ACG) x 3 (T1, T2, and T4) (T3 was excluded due to few participants). Normality checks were carried out on the residuals which were approximately normally distributed. Further, we incorporated the Bonferroni correction procedure to control for the potential inflation of type one error.

Results

The mean number of training sessions was 11.28 sessions (SD 1.32). Table 2 presents the descriptive statistics for all measures. The Shapiro-Wilk test was performed for each group in order to check for normality. The test was non-significant for all variables in the two groups, except from the backwards digit span in the experimental group, which was considered an acceptable result.

Table 2. Descriptive statistics and effect sizes (Hedges'*g*)

Variables and groups	Min-Max	Skewness	(N = Experimental/Control)						
	T1	T1	T1 (*N* = 18/20) *M (SD)*	T2 (*N* = 18/19) *M (SD)*	Hedges'*g*	T3 (*N* = 13/18) *M (SD)*	Hedges'*g*	T4 (*N* = 15/20) *M (SD)*	Hedges'*g*
CLPT	17-36								
EG		.404	23.3 (5.0)	27.1 (5.2)		28.1 (4.4)		27.7 (4.0)	
ACG		-.233	26.4 (3.2)	29.4 (5.1)	$g = -0.44$	26.8 (3.8)	$g = 0.32$	27.8 (3.8)	$g = -0.03$
Digit Span Back	3-9								
EG		.698	5.8 (1.2)	6.6 (1.1)		6.8 (1.5)		7.2 (1.7)	
ACG		-.055	6.3 (1.9)	6.2 (1.4)	$g = 0.31$	7.1 (1.6)	$g = -0.19$	6.8 (2.0)	$g = 0.21$
Odd-One-Out	5-21								
EG		.218	11.5 (4.2)	17.8 (4.1)		15.3 (4.6)		15.7 (3.5)	
ACG		-.314	12.8 (4.6)	15.3 (5.2)	$g = 0.52$	13.9 (4.2)	$g = 0.31$	16.3 (4.0)	$g = -0.15$
Sentence Comprehension	18-85								
EG		-.019	52.0 (19.5)	64.1 (21.0)		72.8 (22.3)		78.3 (23.3)	
ACG		-.107	52.4 (15.9)	60.7 (16.7)	$g = 0.18$	69.3 (11.9)	$g = 0.20$	75.1 (15.3)	$g = 0.16$
Language Comprehension									
TROG-2	64-80								
EG		-.913	78.0 (3.9)						
ACG		-.832	75.1 (3.0)						
Nonverbal Intelligence:									
Matrix Reasoning	12-27								
EG		.458	18.4 (3.3)						
ACG		-.610	20.0 (3.6)						

Note: The table displays Mean, SD for WM, sentence comprehension; TROG-2 and Matrix Reasoning for the experimenatal group (EG) and active control group (ACG) at T1, T2, T3, T4: raw scores and Hedges' *g*.

Table 2 display descriptive results from T1, T2, T3 and T4. Hedges'g was calculated as a measure of effect size of the difference between the experimental- and control-group at T2, T3 and T4. Following Cohen (1977), the effect sizes for verbal WM (CLPT, Digit Span back) and sentence comprehension variables were considered low, ranging from $g = -0.03$ to $g = 0.31$. For visuo-spatial WM (Odd One Out), the effect sizes were medium at post-test, $g = 0.52$. However, the difference diminished over time at half-year follow-up, $g = 0.31$ and at one-year follow-up, $g = 0.15$.

A repeated measure mixed ANOVA was applied to investigate the development of sentence comprehension between timepoints (T1, T2, and T4). Before this analysis we tested if there were significant differences between the two groups at baseline in: age: t (36) = −.58, p = .563, language comprehension: TROG-2: t (36) = −1.48, p = .148, nonverbal intelligence: Matrix Reasoning: t (36) = −1.40, p = .171 or in sentence comprehension: t (34) = −.06, p = .951. Since there were no significant differences between the two groups (EG and ACG), we performed the repeated mixed ANOVA. Results showed significant differences in time: F (2,60) = 158.80, $p < .001$. Post hoc tests using the Bonferroni correction revealed that sentence comprehension improved significantly by an average of 11.37 correct sentences at T2 ($p < .001$) and then improved significantly by 12.07 correct sentences at T4 ($p < .001$). However, there were no significant differences between sentence comprehension, related to group (EG and ACG) (time*group) F (2,60) = 1.24, p = .298. This indicated that one of the groups did not improve significantly more in sentence comprehension compared to the other group.

Discussion

The main purpose of this study was to investigate a face-to-face non-computerized WM training method to improve Danish-speaking school-age children's reading comprehension in a longitudinal design. No WM training studies have been conducted in a Danish setting or with the age group we tested. In the present study, we investigated whether any short- and long-range transfer effects would emerge on either the reading or WM measures using a longitudinal design with two follow-up measures. During the intervention phase, children were trained on a verbal and a visuo-spatial WM task, following the face-to-face procedure described in Henry et al. (2014).

Visuo-spatial WM improved from T1 to T2 in favour of the experimental group, but this effect was no longer present at the one year follow-up. The groups did not differ with respect to reading comprehension, suggesting that a temporary WM capacity improvement did not influence reading comprehension.

The findings are not consistent with the results of the non-computerized study by Henry et al. (2014), that showed significantly larger gains in a trained group compared to a control group on two trained executive-loaded WM tasks, and on two untrained WM tasks at the post-test for English-speaking children. Furthermore, the trained group had significantly higher reading comprehension scores than the control group at a 12-month follow-up; however, Henry et al. (2014) did not include reading comprehension measures at pre-test.

As mentioned above, results in the present study only showed significant improvements and a medium effect size at post-test in visuo-spatial memory in favour of the experimental group, but the effect was not maintained over time. Previous research suggests that domain-specific factors such as verbal information processing and general factors of WM contribute to reading comprehension performance (Carretti et al., 2009), so the question remains, if reading comprehension would have improved, had we succeeded to improve verbal WM? From previous meta-analysis with computerized training, results indicate that WM training leads to improvements in verbal WM, highest in studies of children below age 10, but the gains were not sustained over time, and there was no evidence that WM training leads to improvements in word reading or reading comprehension (Melby-Lervåg et al., 2016; Melby-Lervåg & Hulme, 2013). Melby-Lervåg et al., 2016 concluded that computer WM programs improve skills similar to the ones that are trained, the effect tends not to be long-term and does not generalize to real world measures (see Knudsen & Jensen de López, 2018 for an overview of results and discussions).

There may be several methodological factors bearing upon the outcome of our study. First, the school only allowed us to carry out a four-week training period, which was two weeks shorter than the training period used by Henry et al. (2014), and the training sessions were relatively short compared to many other training studies. We do not know whether a longer training period in our study may have brought about greater improvements, or whether periodic training boosts could enhance WM, and it is beyond the limits of this study to comment further on these ideas. However, the literature does not suggest that longer periods of training show better effects as results are mixed. Loosli et al. (2012) trained participants for 2 weeks, and other studies trained for 5-7 weeks (Dahlin, 2011; Holmes & Gathercole, 2014; Söderqvist & Nutley, 2015) and they all showed an effect in favour of an experimental group, while some of the studies that did not show improvements in reading similarly trained for 5 or more weeks (Chacko et al., 2014; Dunning et al., 2013; Gray et al., 2012; Hitchcock & Westwell, 2017; Holmes et al., 2009; St. Clair Thompson et al., 2010).

The children in our study were older than the children in Henry et al.'s study, which may cause a difference in performance. According to Wass et al. (2012), younger is better when it comes to cognitive training, which may be due to brain plasticity. However, the study by St. Clair Thompson et al. (2010), with 254 children the same age as the children in Henry et al.'s study, showed no improvement on standardized reading tests.

In the present WM training, we did not help the child in finding useful memory strategies and developing meta-cognition, but it would indeed be possible in a one-to-one interaction to support and scaffold the student in developing new and effective memory strategies that fit each child, which may positively improve learning outcomes (Peng & Fuchs, 2017; Vygotsky, 1978; Wood et al., 1976), e.g. following the principles of dynamic assessment (Haywood & Lidz, 2007).

Another possibility is embedding WM training in a classroom setting performed by teachers while working with texts where WM is needed, as in a study by e.g. Garcia-Madruga et al. (2013). Here they trained 4th grade children with reading comprehension tasks in which WM executive processes were involved. Results of the experimental group was compared with an active control group and confirmed improvements in memory, inference and integration. Unfortunately, there were no information of follow-up measures months or years later. However, a study like that raises other research-related considerations such as the control of variables. An embedded approach has the advantage that WM training is situated and integrated into the situation where the skills are needed, and WM training does not interrupt the child in participating in the classroom activities in the way that our WM training outside the classroom did.

Importantly, differences in results may further be due to the use of different reading comprehension tasks. Henry et al. (2014) measured reading comprehension with Wechsler

Objective Reading Dimensions, which assesses the child's ability to make elaborative inferences about a text (Hulme & Snowling, 2009). Our sentence comprehension task had a picture to guide the answers, which presumably did not impose such high cognitive demands as inference construction in a text would, so we might have seen different results if we had included several reading comprehension tasks aimed at taxing WM more heavily.

As suggested by Snow (2002), reading comprehension includes *several* skills, and these may be relatively difficult to capture in a single sentence comprehension task like the one we used, as compared to a text comprehension task. A further limitation in our study is that our language task (TROG-2) exclusively captured grammar and syntax, and hence we were not able to provide a measure of the children's semantic or/and pragmatic language abilities, which are equally important for reading comprehension (Gough & Tunmer, 1986). Future studies should include a measure of semantic language abilities as well in order to broaden theories of children's reading comprehension development.

Finally, an explanation of the lack of positive training results may basically rely on the nature of the WM construct. Empirical research in WM studies suggests that it is not a limited modular capacity influencing reading comprehension in isolation. Following MacDonald and Christiansen (2002), differences in reading may be due to biological factors in combination with reading experiences that cannot be attributed to an isolated capacity. This approach implies, in our view, that children should gain experiences in reading comprehension, and develop their background knowledge (their knowledge about the world), vocabulary, motivation and acceptance of the purpose of reading the text (see for example Snow, 2002).

In conclusion, it was not possible to improve Danish children's reading comprehension by training their WM in this small scaled pilot study. Although we are not able to draw conclusions regarding the effect of the training programme for children struggling with reading disabilities, these findings may contribute to considerations about reading intervention and to the common knowledge among researchers in the field of WM training. The research suggests the need for future studies with sufficient power, active control groups and, importantly, several different measures of reading comprehension at pre-test and one-year follow-up. Studies of that kind may shed light on the role of WM training in reading comprehension.

Although it is important to consider the positive results of training studies in published studies that address the impact of WM training on children's reading abilities, when it comes to advising parents and schools, it may nevertheless be difficult to obtain an accurate picture of results due to publication bias. Studies that find no effect of WM training, like the current study, are difficult to publish (Melby-Lervåg & Hulme, 2013; see de Bruin et al., 2015 for an example). Finally, it may be beneficial to question the notion of WM and instead invest the many 'training hours' on the child gaining experience in reading comprehension or in peer reading activities.

Acknowledgements

A great thanks to Lucy A. Henry, David J. Messer and Gilly Nash for kindly lending us the training materials and for discussions. Any errors are the pure responsibility of the authors. Thanks to the participants, to Lisa Archibald, for reading and advising on the manuscript, and thanks to Masters students at the Clinic for Developmental Communication Disorders, CeDAPS, Aalborg University for helping with data collection. The training study formed part of the PhD dissertation completed by the first author.

Disclosure statement

No potential conflict of interest was reported by the authors.

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