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PAPER

Training and transfer effects of executive functions in preschool children

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Abstract

Executive functions, including working memory and inhibition, are of central importance to much of human behavior. Interventions intended to improve executive functions might therefore serve an important purpose. Previous studies show that working memory can be improved by training, but it is unknown if this also holds for inhibition, and whether it is possible to train executive functions in preschoolers. In the present study, preschool children received computerized training of either visuo-spatial working memory or inhibition for 5 weeks. An active control group played commercially available computer games, and a passive control group took part in only pre- and posttesting. Children trained on working memory improved significantly on trained tasks; they showed training effects on non-trained tests of spatial and verbal working memory, as well as transfer effects to attention. Children trained on inhibition showed a significant improvement over time on two out of three trained task paradigms, but no significant improvements relative to the control groups on tasks measuring working memory or attention. In neither of the two interventions were there effects on non-trained inhibitory tasks. The results suggest that working memory training can have significant effects also among preschool children. The finding that inhibition could not be improved by either one of the two training programs might be due to the particular training program used in the present study or possibly indicate that executive functions differ in how easily they can be improved by training, which in turn might relate to differences in their underlying psychological and neural processes.

Introduction

Executive control involves higher-order cognitive functioning that is critical for goal directed behavior (Welsh, 2002). It includes a number of interrelated processes of which working memory (WM) and inhibitory control are two of the most fundamental functions (Barkley, 1997). Rudimentary forms of WM and inhibitory control are present relatively early in life, and they show a rapid development throughout preschool and early school-age (e.g. Carlson, 2004; Davidson, Amso, Creuss Anderson & Diamond, 2006; Zelazo & Müller, 2002). In addition, WM and inhibition have been shown to be related to a range of abilities such as theory of mind (e.g. Perner & Lang, 1999; Zelazo, Jacques, Burack & Frye, 2002) and academic achievement (e.g. Biederman, Monuteaux, Doyle, Seidman, Wilens, Ferrero, Morgan & Faraone, 2004; Gathercole, Brown & Pickering, 2003), as well as to neurodevelopmental disorders such as Attention-Deficit Hyperactivity Disorder (ADHD; APA, 1994; Martinussen, Hayden, Hogg-Johnson & Tannock, 2005; Wilcutt, Doyle, Nigg, Faraone & Pennington, 2005).

The great importance of executive functioning in much of human life has led researchers to design studies for improving executive functions. Klingberg and colleagues (Klingberg, Forssberg & Westerberg, 2002; Klingberg, Fernell, Olesen, Johnson, Gustafsson, Dahlström, Gillberg, Forssberg & Westerberg, 2005) showed that children with ADHD (7–12 years old) can improve WM, inhibitory control and reasoning ability by intense WM training (25–40 min/day during 5 weeks). Two other training studies of school-aged children with ADHD (Kerns, Eso & Thomson, 1999; Shalev, Yehoshua & Mevorach, 2007) investigated the effects of attentional training (30–60 min, twice weekly for 8 weeks). These attentional training programs have included a wide variety of attentional processes such as vigilance, selective attention, divided attention, the ability to switch attention between stimuli or tasks, and inhibitory control. Kerns and colleagues (1999) found significant training effects on sustained attention, inhibitory control, mazes, and a math test but no effect on WM. Shalev and colleagues (2007), who only studied academic outcomes, found no effects of attentional training on mathematics, although significant effects on passage copying and reading

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comprehension. Finally, Rueda and colleagues (Rueda, Rothbart, McCandliss & Posner, 2005) studied normally developing preschool children and found that after 5 days of attentional training, the intervention group had improved significantly more than a control group on the Kaufman Brief Intelligence Test (K-BIT) in their community-based sample of 4-year-olds. However, no effect on K-BIT was found for 6-year-olds. In addition, they found no significant training effects on a version of the flanker task (i.e. a measure of inhibitory control) in either age group. Conclusively, the attentional training program used by Rueda and colleagues (2005) was not able to increase inhibitory control in preschoolers as measured by improved performance on a flanker task and the results for intelligence were inconsistent as effects were found for only one age group. The effect on WM was not investigated in this study.

The findings described above show promising effects of cognitive training but also point to inconsistencies between different studies regarding what types of effects that can be demonstrated for different training programs. At least three different types of effects can be found. First, there are likely to be practice effects on the tasks included in the training program. Second, there could be training effects on non-trained tasks measuring the particular cognitive aspect targeted by the training program. Third, there could be transfer effects in that effects generalize to either related cognitive constructs (i.e. WM training having effects on inhibition) or behaviors associated with the trained construct (i.e. cognitive training having effects on symptoms of inattention, problem solving or school performance).

Another important issue in this area of research relates to the fact that if cognitive interventions are to be used as remediation or prevention of cognitive deficits, early intervention is crucial; yet only one previous study (Rueda *et al.*, 2005) has conducted training in children below school-age. Another limitation of previous research is that while effects of WM training and general attentional training have been studied, no previous training program has focused exclusively on inhibitory control. Previous studies of attentional training have included inhibitory task paradigms such as the flanker and Stroop tasks (Rueda *et al.*, 2005; Shalev *et al.*, 2007), but also tasks requiring sustained attention or stimulus discrimination, making it impossible to determine which function has contributed to the effects of these programs. As cognitive functions may vary in how easily they can be improved through training, focusing on specific cognitive functions and thereafter possibly use of combination of those training paradigms that have documented effects, appears to be the most rational approach. Focusing on inhibitory control is particularly important when studying preschoolers as they are more challenged by inhibitory demands compared to WM demands, whereas the reverse is true for older children and adults (e.g. Davidson *et al.*, 2006).

In the present study, we investigated the effects of two specific training programs focusing on either visuo-spatial WM or inhibitory control in a community-based sample of preschool children. In contrast to previous WM training studies (Klingberg *et al.*, 2002, 2005), the training program used in the present study included only visuo-spatial WM tasks. This was motivated by the fact that current meta-analytic findings have shown that visuo-spatial WM is more clearly associated with ADHD compared to verbal WM (Martinussen *et al.*, 2005). The inhibition training program included three different task paradigms as it has been argued that there are several different types of inter-related inhibitory function that are all related to ADHD (Barkley, 1997).

Several previous theoretical models have argued for a strong connection between WM and inhibition (e.g. Engle & Kane, 2004; Roberts & Pennington, 1996). In addition, an imaging study of normally developing adults that included the same task paradigms as the training programs (McNab, Strand, Thorell, Bergman & Klingberg, 2007) showed that WM and inhibition tasks activated overlapping areas in the ventrolateral prefrontal cortex and this might be the underlying neural basis for transfer between WM and inhibition. We therefore hypothesized that both training programs would have effects on the trained construct, as well as show transfer effects to the other (i.e. WM would have effects on inhibition and vice versa). Furthermore, performance of both WM and inhibitory tasks requires continuous attention, and we therefore hypothesized that we would find transfer effects to laboratory measures of attention for both types of training.

Methods

Participants and procedure

The present study was approved by the ethical committee at the Karolinska Institute, Stockholm, Sweden. All children between the ages of 4 and 5 years (*M* = 56 months, *SD* = 5.18) at four different preschools were asked to participate in the study. Only two parents at the selected preschools did not agree to let their child participate in the study. Informed, written consent from one caregiver was obtained for all participating children. Children at two of the preschools formed the experimental groups and these children were randomly assigned (matching the groups with regard to age and gender) to either the WM training group (*n* = 17, nine boys, mean age = 54 months) or the inhibition training group (*n* = 18, nine boys, mean age = 54 months). All children at the third preschool formed the active control group (*n* = 14, seven boys, mean age = 58 months) and all children at the fourth preschool formed the passive control group (*n* = 16, seven boys, mean age = 60 months). As there were gender differences with regard to some of the outcome measures and the children in the two training groups were a few months younger compared to the children in the passive control group, all analyses were conducted controlling for age and gender. None of the children had received a psychiatric diagnosis and none of them met the symptom criteria for ADHD according to parental or teacher ratings on the ADHD Rating Scale-IV (DuPaul, Power, Anastopoulos & Reid, 1998).

During 5 weeks, children in the two training groups and the active control group played computer games for 15 minutes each day they attended preschool. Children in the training groups played games that were especially designed to improve either visuo-spatial WM or inhibitory control (see further description below). Children in the active control group played commercially available computer games that were selected based on their low impact on WM or inhibitory control. Instead, these games included tasks that required the child to handle the computer mouse, for example by clicking on a certain place on the screen to make a selection. Both the training program and the commercial computer games were administered to the child in a separate room at the preschool, with an experimenter present during the entire session. This experimenter gave continuous feedback to the children during the training. In addition, the children in the two training groups and the active control group were allowed to choose small gifts (e.g. bubble blowers, toy cars) at the end of each week of training and a larger gift (e.g. a stuffed animal) after completing the posttests. Children in the passive control group took part in only pre- and posttesting.

Training program

The computerized training programs used in the study were developed by the authors in collaboration with the company Cogmed systems (Stockholm, Sweden). The inhibition and WM training programs had a similar design, both programs included an algorithm for continuously adapting the difficulty level based on performance, and both programs had an identical interface regarding rewards and feedback for correct performance. The two training programs included five different tasks each, although only three tasks were administered to the child each day according to a rotating schedule. Each task took about 5 minutes to complete, which meant that the children trained for about 15 minutes each day. Visual feedback was given for each trial and these feedbacks were translated into points that were presented on the screen as fruits at the end of each day of training. The children advanced in levels of difficulty based on accuracy. For each correct trial, the difficulty increased by one-third of a level (i.e. three correct trials were required in order to advance to the next level), and for each incorrect trial, difficulty decreased by two-thirds of a level.

The WM program was based on previous training programs (Klingberg *et al.*, 2005), but focused specifically on visuo-spatial WM. For all tasks, a number of visual stimuli were presented sequentially on the computer screen and the child had to remember both their location and their order and respond by clicking with the mouse on the targets one at a time in the correct order. The presentation time for each stimulus was 1000 msec and the time between each stimulus was 500 msec. Task difficulty was manipulated through increasing the number of stimuli that had to be remembered. Performance is reported as the highest level obtained for each training session where each level corresponds to the number of items that the child had to remember (i.e. 2 items at level 2, 3 items at level 3, etc.).

The inhibitory control program included five tasks based on three well-established task paradigms known to tap the three most fundamental forms of inhibition: inhibition of a prepotent motor response (go/no-go paradigm; Trommer, Hoeppner, Lorber & Armstrong, 1988), stopping of an ongoing response (stop-signal paradigm; Logan & Cowan, 1984) and interference control (flanker task; Botvinick, Nystrom, Fissell, Carter & Cohen, 1999). There were two go/no-go tasks in which the child was told to respond ('go') when a certain stimulus (e.g. a fruit) was presented, but to make no response ('no-go') when another stimulus (e.g. a fish) was presented. There were also two versions of the stop-signal task in which the child was instructed to respond as quickly as possible when a stimulus (e.g. a fruit) was presented, except when that stimulus was followed by a stop-signal (e.g. a fish). Finally, the inhibition training program included one version of the flanker task. Five arrows pointing either right or left were presented in a row and the goal of the task was to make a response in accordance with the direction of the arrow in the middle (e.g. pressing a button to the right if the arrow was pointing to the right) while ignoring the arrows on the side. In the inhibition tasks, difficulty was manipulated through decreasing the time allowed for making a response.

Pre- and posttest measures

Pre- and posttesting was conducted by an experimenter who was blind to the group assignment of each child. The order in which the laboratory tests were administrated was randomized and the same order was used for pre- and posttests. Altogether, eight different pre- and posttest measures were used: (a) Interference control was assessed using an adapted version of the Day-Night Stroop Task (Gerstadt, Hong & Diamond, 1994). This version (Berlin & Bohlin, 2002) includes two pairs of opposites (day and night; boy and girl) and the child is instructed to say the opposite as quickly as possible when a picture is presented on the computer screen. The outcome measure used was the total number of errors; (b) Response inhibition was measured by the number of commission errors (i.e. making a response when instructed not to do so) on a go/no-go task (Berlin & Bohlin, 2002); (c) The Span board task from WAIS-R-NI (Wechsler, 1981) was used to assess visuo-spatial WM. The score used was the mean number of points on both the forward and backward condition; (d) A word span task (Thorell, 2007; Thorell & Wåhlstedt, 2006) was used to measure verbal WM. This task is identical to the Digit Span Subtest from

WISC-III (Wechsler, 1991), although unrelated nouns are used instead of digits. The score used was the mean number of points on both the forward and backward condition; (e) An auditory continuous performance task (CPT) from NEPSY (Korkman, Kemp & Kirk, 1998) was used to assess auditory attention. The outcome measure used was number of omission errors; (f) To measure visual attention, the number of omission errors on a go/no-go task (Berlin & Bohlin, 2002) was used; (g) Number of points on the Block Design Subtest from WPPSI-R (Wechsler, 1995) was used to assess problem solving; (h) Response speed was measured by the children's mean reaction time on correct responses on the go/no-go task (Berlin & Bohlin, 2002).

Results

All children in the study were able to understand the tasks included in the training programs and there were no withdrawals from the study. However, due to absence from preschool or refusal to participate on a particular day, not all children had complete data for the 25 training sessions. A total of three children (one in each of the two training groups and one in the active control group) had participated in only 15 sessions or less and were therefore excluded from the study. The mean number of training days was 23 (*SD* = 2.5) for the WM training group, 23 (*SD* = 2.8) for the inhibitory training group, and 22 (*SD* = 3.2) for the active control group. The groups did not differ on any of measures collected at pretest, all *F*s < 1.21, *ns*.

Performance on trained tasks

During the 5 weeks of training, all measures of performance for the WM and inhibition training groups were recorded and later analyzed. Figure 1 displays performance over time on the trained task paradigms. The values shown are the highest three levels (standardized values) reached for each training session. In addition, the highest three levels achieved from day 2–4 was compared with the last three days using repeated measures *t*-tests to study improvement over time on the trained tasks. The first day of training was not included in these analyses due to the steep increase from day 1 to day 2, which could reflect factors such as failure to understand the tasks rather than actual improvements in cognitive functioning. The results of the *t*-tests showed that the children had improved significantly on all trained tasks

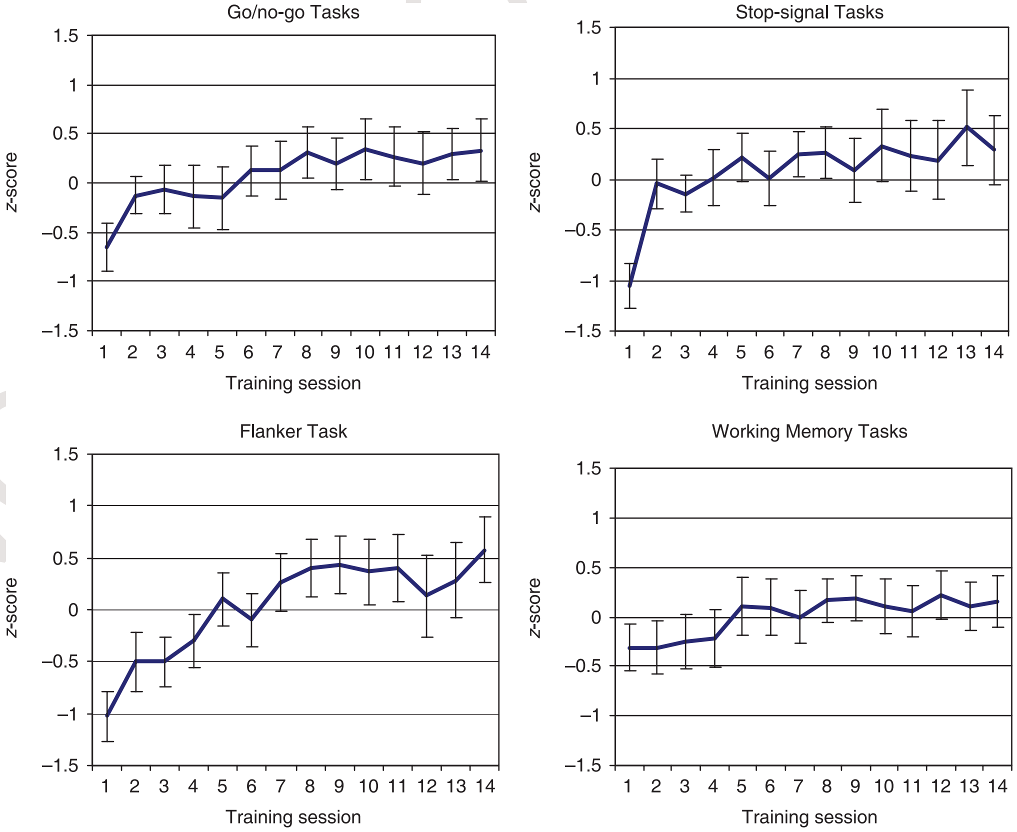

Figure 1 *Training curves showing the obtained level (z-value) and standard errors of the mean throughout the 5 weeks of training*[1] *for the different task paradigms included in both the inhibition training program (go/no-go tasks, stop-signal tasks, and Flanker task) and the working memory training program.*

[1] The children performed three of five tasks each day. Thus, for each task, there are data for 15 sessions and we included only 14 sessions in the graphs as several children were absent from preschool on at least one day.

Table 1 *Means and standard deviations at T1 (pretest) and T2 (posttest for all measures), as well as results of one-way ANCOVAs with planned comparisons and effect sizes* (d) *for the two training groups relative to the combined control group*

		Working memory group (WM) *M* (*SD*)	Inhibition group (IN) *M* (*SD*)	Active control group (C) *M* (*SD*)	Passive control group (C) *M* (*SD*)	Effects	
						Overall *F*-value	Planned contrasts
Working memory							
Span Board (points)	T1	2.85 (1.13)	2.61 (0.71)	3.11 (0.96)	3.21 (0.85)	5.98**	WM > C*
	T2	4.00 (1.19)	2.71 (0.58)	3.78 (0.87)	3.64 (1.17)		
	T3	.89	−.43				
Word Spans (points)	T1	3.25 (0.58)	3.29 (1.05)	3.81 (0.75)	3.79 (0.78)	4.14*	WM > C**
	T2	4.25 (0.72)	3.71 (0.81)	4.06 (0.42)	4.04 (0.66)		
	d	1.15	0.26				
Inhibition							
Stroop-like task (errors)	T1	15.88 (8.00)	17.94 (12.70)	16.82 (12.54)	15.53 (8.40)	0.83, *ns*	
	T2	10.75 (6.95)	12.69 (9.63)	14.27 (9.55)	13.27 (7.76)		
	d	.41	.37				
Go/no-go (commissions)	T1	4.88 (4.99)	4.25 (3.86)	4.42 (2.54)	4.13 (2.59)	0.13, *ns*	
	T2	4.31 (3.52)	4.50 (4.38)	4.00 (3.54)	3.47 (2.92)		
	d	0.01	0.23				
Attention							
Auditory CPT (omission)	T1	9.87 (6.25)	6.69 (5.26)	5.91 (6.12)	5.13 (3.38)	2.77+	WM > C*
	T2	5.53 (3.94)	4.81 (5.06)	7.09 (6.88)	3.53 (3.40)		
	d	.52	.12				
Go/no-go (omissions)	T1	6.31 (6.57)	4.27 (4.08)	4.58 (5.32)	3.53 (4.00)	3.30*	WM > C*
	T2	3.12 (4.26)	2.93 (3.51)	4.08 (6.46)	4.33 (5.54)		
	d	.74	.32				
Problem solving							
Block design (points)	T1	20.69 (7.30)	18.50 (5.02)	25.08 (7.05)	23.00 (4.93)	0.49, *ns*	
	T2	24.75 (6.80)	22.38 (5.82)	29.33 (6.00)	24.93 (5.12)		
	d	.31	.28				
Response speed							
Go/no-go task (RT)	T1	1116.97 (432.93)	1025.28 (360.25)	918.42 (449.53)	870.62 (185.08)	0.34, *ns*	
	T2	917.31 (287.88)	847.62 (317.44)	745.42 (208.80)	874.05 (217.70)		
	d	.50	.34				

+ $p < .10$; * $p < .05$; ** $p < .01$.
Note: All mean values are raw scores, without the influence of covariates.

included in the WM training, *t*s(15) > 1.96, $p < .05$. For the inhibition training, the children had improved significantly on the go/no-go tasks, *t*(15) > 3.70, $p < .01$, and the flanker task, *t*(15) > 2.92, $p < .05$, but not on the stop-signal tasks, *t*(15) > 1.13, *ns*.

Effect on non-trained tasks

Effects on non-trained tasks, means and standard deviations for pre- and posttest scores for each of the four groups are presented in Table 1. With regard to effects of the training, the active control group was compared with the passive control group using one-way analyses of covariance (ANCOVAs) with the difference scores between pre-and posttest measures as dependent variables and gender and age as covariates. As no significant effects were found for any of the measures, all *F*s(1, 24) < 2.79, *p*s > .10, the two control groups were combined in all subsequent analyses.

In another set of similar ANCOVAs (see Table 1), the two training groups were compared with the combined control group. In case of a significant, or marginally significant, overall group effect, planned comparisons were conducted in which each of the two training groups were compared with the control group. Effect sizes were calculated using Cohen's (1988) effect size formula (*d*), where an effect size of .20 is considered small, an effect of .50 medium, and an effect of .80 large (see Table 1).

With regard to the WM tasks, the results showed a significant effect of training on both visuo-spatial WM and verbal WM. Planned comparisons showed that for both types of WM, the WM group, but not the inhibition group, showed significantly larger improvement over time compared to the control group. The effect size for the comparison between the WM group and the control groups was large for both spatial and verbal WM. For the comparisons between the inhibition group and the control groups, both the effect of spatial and verbal WM was small.

For the inhibitory control tasks, the training effects were not significant for either commission errors on the go/no-go task or for errors on the Stroop Task and all effects sizes for both training groups were small. A significant overall effect was, however, found for omission errors on the auditory CPT, as well as a marginally significant effect on omission errors on the go/no-go task. Planned comparisons revealed that the WM group, but not the inhibition group, had improved significantly more over time compared to the control group. Effect sizes were in the medium range for the comparisons between the WM group and the controls and small for the comparisons between the inhibition group and the controls. No significant effects were found for problem solving or for reaction time on the go/no-go task. All effect sizes for these non-significant comparisons were small.

Finally, all results were reanalyzed using change in reaction time and change in problem solving (i.e. variables that have been shown to be related to executive functions) as additional covariates. However, the results of these analyses showed that none of the effects changed from being significant to non-significant or vice versa.

Discussion

This study is the first to focus specifically on training of inhibition and the first study of WM training in children below school-age. The main findings were that WM training was effective even among preschool children insofar as it had significant effects on non-trained WM tasks within both the spatial and the verbal domains, as well as significant transfer effects on laboratory measures of attention. On the other hand, training of inhibitory control did not have any significant effects relative to the control group, despite the fact that the children improved on at least some of the trained tasks.

Working memory training

The finding of a significant effect of WM training on non-trained WM tasks within both the spatial and the verbal domains is in line with previous studies of WM training in school-aged children (Klingberg *et al.*, 2002, 2005). Thus, it is possible to use WM training to improve cognitive functioning also in preschool children, although it is for future studies to investigate how long-lasting these effects are. For school-aged children, 90% of the effect of WM training remained after 3 months (Klingberg *et al.*, 2005). An interesting finding of the present study was that, unlike Klingberg *et al.* (2002, 2005), our training program only included tasks of visuo-spatial WM. Thus, there was a transfer effect of visuo-spatial training to the verbal domain of WM, which is in line with previous neuroimaging findings showing evidence of supramodal WM areas (i.e. areas that are active irrespective of the type of stimuli being held in WM) within the parietal and prefrontal cortex (Curtis & D'Esposito, 2003; Hautzel, Mottaghy, Schmidt, Zemb, Shah, Muller-Gartner & Krause, 2002; Klingberg, 1998). These are also the cortical areas where brain activity has been shown to increase as an effect of WM training (Olesen, Westerberg & Klingberg, 2004).

Our finding that the effects of WM training could not be generalized to inhibitory functioning is in line with results presented by Rueda *et al.* (2005), who also failed to find a significant effect of attentional training on a flanker-like task. However, Klingberg and colleagues (2002, 2005), and Kerns and colleagues (1999) did find a significant effect of WM or attentional training on the Stroop task. In addition, Klingberg *et al.* (2002, 2005) as well as Rueda *et al.* (2005) found that training effects could generalize to problem solving. These inconsistencies between the studies cannot easily be explained but could perhaps be a result of differences in sample characteristics (e.g. school-aged children being more easily trained compared to preschool children or effects being larger for clinical groups that have more severe executive deficits), length of training (e.g. 15 minutes in the present study versus 25–40 minutes in the studies by Klingberg and colleagues), or choice of task measuring inhibitory control and problem solving (e.g. flanker task and K-BIT in the study by Rueda and colleagues versus a Stroop-like task and Block design in our study).

Inhibition training

There are several possible explanations for our finding that WM training, but not inhibition training, showed effects to non-trained tasks. First, the neuropsychological basis of WM and inhibition are at least partly different. Different parts of association cortex differ in their densities of receptors and it is possible that this could have effects on the plasticity of different areas (Kuboshima-Amemori & Sawaguchi, 2007). Second, inhibition of an ongoing or prepotent response is presumably a relatively short neural process, occurring over a few hundred milliseconds, while keeping information in mind is based on sustained activity in both parietal and prefrontal areas during several seconds (Curtis, Rao & D'Esposito, 2004; Funahashi, Bruce & Goldman-Rakic, 1989). Furthermore, in tasks such as the go/no-go task or the stop-signal task, inhibition is required on only a minority of the trials, whereas WM is demanded on each trail. Thus, given an equivalent total training time of 15 minutes, the time devoted to the key neural process being trained is much shorter for the process of inhibition than for WM. Third, previous training studies (Klingberg *et al.*, 2002, 2005) have shown that it is important to adapt the difficulty level so that the child is training at an optimal level throughout the training period. In WM tasks, difficulty can easily be increased gradually through increasing the number of items that needs to be remembered, but much less is known regarding how to best manipulate task difficulty in inhibitory control tasks. Fourth, some of the children already performed relatively well on the go/no-go tasks before the training, leaving relatively little room for improvement on this task, although the same was not true for the Stroop-like task. Finally, it should be noted that the inhibition training program included three different training paradigms and it is possible that training on one of these paradigms would have an effect, although the total amount of training for each specific paradigm was too short in the present study to detect such an effect.

Another important finding of the present study was that although inhibitory training did not lead to effects on non-trained tasks, the children did show improvement on several of the trained tasks. It is interesting to note that effects were not even found for the go/no-go task, even though tasks based on the same paradigm were included in the training program. This indicates that improved performance during training is not sufficient for transfer, and emphasizes the need to always use non-trained tasks as the outcome measures. One possible explanation for this discrepancy between effects on trained and non-trained tasks is that subjects developed a specific strategy for solving the trained tasks, but it was not possible to apply this specific strategy in a general way to other cognitive tasks. In line with this interpretation, it has for example been found that learning to remember very long series of digits through a task specific strategy does not result in better memory for letters (Ericsson, Chase & Faloon, 1980).

Conclusions and future directions

In conclusion, we found that fifteen minutes of visuo-spatial WM training per day for 5 weeks had significant effects on both trained and non-trained WM tasks within both the verbal and the spatial domains. WM training also had effects on laboratory measures of attention, but not on inhibitory control tasks and problem solving. Children in the inhibition training groups improved significantly on several of the trained tasks, but this effect did not generalize to non-trained tasks of either inhibition or other executive functions. This does not preclude the possibility that a modified version of the inhibitory training could have effects, but it could also mean that cognitive functions differ in terms of how easily they can be trained. These differences might be explained by differences in the anatomical basis and time-course of the underlying psychological and neural processes of WM and inhibition.

The significant effects of WM training, with large effect sizes for non-trained tasks of both verbal and spatial WM and medium effect sizes for measures of attention, indicate that this type of training could perhaps make a significant impact with regard to early intervention of children with WM deficits, although this is an issue for future studies to investigate. In addition, the strong connection between WM and ADHD (Barkley, 1997; Martinussen *et al.*, 2005; Willcutt *et al.*, 2005) suggests that WM improvement could also be valuable in decreasing ADHD symptom levels. Effects on ADHD symptoms have been found in a previous study of WM training in clinical samples of school-aged children (Klingberg *et al.*, 2005) as well as in a study of attentional training (Shalev *et al.*, 2007). However, this is still a relatively new area of research and it is for future studies to further investigate which cognitive functions can be trained and to what extent the effects of cognitive training can be generalized to other cognitive functions and behavior problems.

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