

Computerized Working Memory Training in Group and the Effects of Noise – A Randomised  
Pilot Study with 7 to 9 year old Children.

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## Table of Contents

Abstract.....	i
Acknowledgements.....	ii
Table of Contents	
Background.....	5
Working Memory.....	5
Multicomponent Model.....	6
Functional Neuroanatomy.....	8
Measures and Applications of WM.....	8
Working Memory, development and education.....	10
Training induced improvement of WM, Attention and other Cognitive Functions.....	11
Arousal and Performance.....	14
Aims of the Present Study.....	16
Methods.....	17
Participants, selection and inclusion criteria.....	17
Procedures.....	18
Apparatus.....	18
Pre- and Post-intervention tasks.....	19
The computerized Working Memory Intervention.....	21
Statistical Analysis.....	25
Results.....	26
Results of Intervention.....	26
Within Training Group Analysis.....	27
Effects of noise on groups and tasks.....	28
Discussion.....	30
Implications of the Intervention.....	30
In Contrast to Similar studies.....	33
Limitations.....	33
Conclusions.....	33
References.....	35
Appendix A.....	41
Appendix B.....	43

The current study examines the effects of a computerised Working Memory (WM) intervention in elementary school children when training in groups of various sizes. It further examines the effects of noise during the performance of WM tasks. The children included were 7 – 9 years old and were randomly assigned to control and training groups based on Raven's scores. Results showed an improvement of verbal WM, backward digit span task, and of visuospatial WM, on the visuospatial span task. Furthermore, the results indicated that group size and performance in the interventions exercises had a greater influence on visuospatial WM performance than on verbal WM performance. The results of the study also suggest that computerized WM training in group is less than optimal. Regarding noise, the visuospatial WM task showed an interaction effect with noise when all participating children were divided into two groups based on teacher rated school achievement. Noise influenced the results positively in average/high school achievers while not in low school achievers.

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Recent studies on the effects of systematic cognitive training of Working Memory (WM) and/or attention in children (Klingberg et al., 2005; Klingberg, Forssberg & Westerberg, 2002; Rueda, Rothbart, McCandliss, Saccomanno & Posner, 2005) have raised interest amongst psychologists, teachers and the public at large. This widespread attention could be due to the fact that schools of today are ridden with problems concerning attention, distraction and performance. Many children find it very difficult to achieve the expected results. Pinpointing the different reasons and finding viable solutions for the performance related problems that some children experience is an aspiration in the interdisciplinary field of WM research. The processes behind WM and its effects upon human cognitive performance have been studied for a number of years (Baddeley, 1992; Goldman-Rakic, 1987; Engle, Cantor & Carullo, 1992). It is though first in recent years that studies have investigated the effects of training WM and explored the possibilities of influencing working memory capacity (WMC). The possible long term potential of WM training and the mechanisms behind its effects on cortical plasticity are still however largely unknown.

### *Working Memory*

The term Working Memory (WM) was first introduced by the cognitive psychologists Miller, Galanter and Pribram (1960) in their book “Plans and structure of behavior”. Today, several different definitions of WM exist which illuminate different aspects of the concept depending on the context in which they have evolved (Baddeley, 1992; Goldman-Rakic, 1987). Most definitions of WM, however, share the following core features: firstly, a temporal storage of information and secondly, the ability to manipulate that information. WM is a concept that by most definitions share common features with other cognitive structures, such as attention and short term memory. In our work we have chosen to rely mostly on Baddeley’s (1992) multicomponent model. Baddeley provides the following definition of WM:

“The term working memory refers to a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning.” (Baddeley, 1992, p. 556)

WM can also be described functionally as containing a maintenance part and a retrieval part (Unsworth & Engle, 2007). The maintenance aspect is an attentional component discerning new information from surrounding distractors. Both the maintenance part and the retrieval part are necessary for succeeding despite distraction, internal and external (Unsworth and Engle, 2007). Individual differences in WM are thus related to the extent one can ignore and attenuate the correct stimuli (Unsworth & Engle, 2007; Engle, Tuholski, Laughlin & Conway, 1999; Kane, Bleckley, Conway & Engle, 2001).

To utilize the limited capacity of WM it is required that the individual is capable of prioritizing relevant from irrelevant information. Some view this ability, which can be referred to as inhibition, as a separate and independent construct (Demetriou, Christou, Spanoudis & Platsidou, 2002; Luna, Garver, Urban, Lazar, & Sweeney, 2004) while others regard it as a part of the WM construct (Unsworth & Engle, 2007; Engle et al., 1999; Kane et al, 2001) Engle et al. (1999) and Kane et al. (2001) focus deeply on the issues of inhibition through the concept of “controlled attention” or “executive control” deeming it a central entity of Working Memory Capacity (WMC). Further theories in this area claim that WM is needed mostly when one has to override automatic tendencies (Unsworth & Engle, 2007). WM can thus also be considered an override system when needing to control automatic behaviour and to overcome distraction.

### *The Multicomponent Model*

The multicomponent WM model consists of a four part system: (1) the central executive, (2) the phonological loop, (3) the visuospatial sketchpad, and (4) the episodic buffer (Baddeley 2007).

The central executive functions as an attentional control system that focuses on three components: (1) to activate through controlled retrieval, (2) to maintain activation, (3) and to block interference through inhibition of distractors (Engle et al., 1999). The central executive is considered to be necessary for the attentional control of action and is based on the Supervisory Attentional System model by Norman and Shallice (as cited in Baddeley, 2007). The system is activated when it is functional to override automatic habits.

The phonological loop holds auditory information and is divided into two parts: a storage component and a sub-vocal rehearsal mechanism (Vallar & Papagano, 2002; Baddeley, 2003;

Gathercole, 2004a). The rehearsal mechanism is said to aid recall of dissimilar sounding objects, such as “pit, day, cow, pen, sup” (Baddeley, 2007) however when it comes to actual words phonetic similarity is more important to recall than is its semantic meaning (Baddeley, 2003). The phonological loop is a crucial component in language acquisition. There is a proven positive correlation between non-word repetition (analogous to sub-vocal rehearsal) and vocabulary acquisition in children. The phonological loop rehearses pseudo and non-familiar words; which is assumed to aid language acquisition (Gathercole & Adams, 1994)

The visuospatial sketchpad is the part of the multicomponent model that focuses on objects or stimuli with visual or spatial features. The visuospatial sketchpad could be part of a passive visual store and part of a more active spatial control process (Gathercole, 2004; Rudkin, Pearson & Logie, 2007). Like the phonological loop the visuospatial sketchpad can only hold a limited amount of objects in its store. Since the visual world is rich in stimuli, consisting of numerous details such as colour; shape; and location, there is a vast amount of details to attend to. The spatial component is thought to keep dynamic information about movement and orientation of objects through active rehearsal, while simultaneously sustaining the information already in the visual store (Rudkin et al., 2007). The rehearsal mechanism in this component is suggested to be aided by eye movements (Postle, Idzikowski, Della Sala, Logie & Baddeley, 2006). Wheeler and Triesman (2002) have proposed a storage system outside of the visuospatial sketchpad that can be accessed when attention demands it. As far as function goes, the visuospatial capacity is a stable predictor of non-verbal intelligence (Wheeler & Triesman, 2002). The visuospatial sketchpad is needed in different types of tasks involving spatial orientation and object recognition (Baddeley, 2003). It is argued that visuospatial Working Memory (VSWM) operates as a mental blackboard in tasks requiring arithmetic and that VSWM therefore is closely associated with mathematical ability (D’Amico & Guarnera, 2005).

The episodic buffer, the latest addition to the model, is described as an interface between long-term memory and the WM subsystems, and between the components themselves (Baddeley, 2000). It enables the integration of different modalities of information from long-term memory and the WM subsystems into a limited pool of components (Baddeley, 2007).

### *Functional Neuroanatomy*

It has been demonstrated that three frontal regions; mid-dorsolateral, mid-ventrolateral and dorsal anterior cingulate cortex, are activated by different cognitive tasks. These tasks include response conflict, WM, novel information and perceptual difficulty; all being suggestive of a specific prefrontal network activated during cognitive tasks (Duncan & Owen, 2000).

The Prefrontal Cortex (PFC) as a whole has a distinct role in cognitive control, and it is also connected to the maintenance of stimulus representations, for example keeping and processing bits of information (Mercado, 2008). Cognitive control and maintaining stimuli are intricate parts of fluid intelligence. Cognitive control entails such functions as maintaining and manipulating stimulus representations, coordination of decision making and also memory search ability (Mercado, 2008). Fluid intelligence is correlated with neural plasticity in humans. Intelligence or intellectual capacity is connected to various parts of the brain, amongst others the structure and activity in the PFC, general neural processing speed, adaptability and efficiency (Mercado, 2008). Cognitive control and the use of strategies are linked to WM (Kane & Engle, 2002, Mercado, 2008).

The different components of WM seem to have different locations neuroanatomically (Baddeley, 2007). It has also been made clear that while there does exist a dorso-ventral dissociation when examining spatial and non-spatial tasks, this is only applicable to the posterior cortex (Wager & Smith, 2003). Frontal cortex activation does not show signs of lateralization when conducting WM tasks on a demanding level (Wager & Smith, 2003). It has also however been shown that the phonological loop resides mainly in the left parietal and temporal lobes (memory storage) and in the left frontal regions (sub-vocal rehearsal). The sub-vocal rehearsal incidentally seems to lie close to Broca's area (Paulesu, Frith, & Frackowiak, 1993). The visuospatial component of WM however has been found to lie mainly in right hemisphere, particularly in the right pre-frontal cortex, occipital lobe and pre-motor area (Jonides, Smith, Koeppe, Awh, Minoshima & Mintun, 1993).

### *Measures and Applications of WM*

WM measures usually involve tasks that require both storage and processing capacity, such as reading span, spatial span, digit span, and counting span. The different components of WM are measured with different tasks. Investigating the phonological loop typically involves

auditory cues intended for recall (Baddeley, 2000). A frequently used test is a backward digit-span, in which participants are given a series of numbers to be repeated in reverse order, this often involves sub-vocal rehearsal (Baddeley, 2007). Vocalisation (sub-vocal rehearsal) involves representations of actually existing words, for example a digit span. The potential degeneration of these while in storage could turn the number “five” into “ive”, and this however can easily be repaired during rehearsal and subsequent recall simply by using the actual words that were presented. In a digit span the following scenario is plausible: “-ive” becomes “five” and never “live”, or “mive” simply because they are not numbers (Baddeley, 2000). When measuring VSWM, the tasks often involve novel stimuli presented which the subject later is asked to recall. In these types of tasks the subject cannot benefit from the vocalization of existing cues. It has been suggested that eye-movement during encoding can work similarly to sub-vocal rehearsal; however evidence of this has yet to surface (Baddeley, 2000). Other proposed ideas in relation to the differences one encounters when testing the WM components include attentional demands upon the performance of sub-vocal rehearsal and its (yet to be fully understood) visuo-spatial relative (Baddeley, 2007). Subvocal rehearsal is not straining and is quite automatic; the visuospatial sketchpad however demands more attention when performing a related task.

WM measures have proven to detect large degrees of individual differences (Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle 2005). Engle (1992) presents two hypotheses regarding the cause of individual differences on WM span measures. According to the general capacity hypothesis the individual performance on a WM measure reflects a stable trait in the individual, independent of the specific WM task being carried out. The strategic allocation hypothesis states that individual differences on WM tasks reflects the usage of strategies (Engle, 1992). According to this hypothesis high performers are better at using strategies and therefore have a greater ability to use their WM capacity more resourcefully.

Turley-Ames & Whitfield (2003) investigated the effect of strategies on an operation span task, such as an exercise involving a math problem and unrelated words, for example a dual task involving both storage and processing information. Strategies were defined as methods aimed at facilitating storage and/or processing. Their results showed that the low span group (individuals who perform poorly on WM tasks) in their study significantly improved their performance after being demonstrated how to use a rehearsal strategy, while the high span group (individuals who perform well on WM tasks) did not profit as much. It is possible that an individual's WM span score reflects both capacity and the use of strategy. Hence, to

improve the measurement of WM capacity they argue the importance of controlling the use of strategy during the performance of WM tasks (Turley-Ames & Whitfield, 2003).

WM performance and level of dopamine have been shown to interact (Goldman-Rakic & Muly, 2000). Söderlund and Loftesnes (as cited in Söderlund, 2007) also suggest a relation between presumed levels of dopamine and cognitive performance measure using WM-related tasks. Presumed high levels of dopamine are associated with high performance on cognitive tasks (Bäckman, Ginovart, Dixon, Wahlin, Wahlin & Haldin, 2000; Söderlund, Sikström & Smart, 2007).

Many studies investigating WM concern themselves with applying their findings to performance on specific tasks and a wider applicability of WM. Making the concept of WM even more applicable are theories connecting WM with IQ or Gf. The general findings point toward a correlation between Gf and WM (Unsworth & Engle, 2007; Kane, Hambrick & Conway, 2005). In support of these claims Kane et al. (2006) suggests WM to be predictive of Gf. The initial evidence for such claims was produced by Daneman and Carpenter (1980, 1983), finding significant correlations between reading comprehension and WM span-tests. Further research has shown results indicative of WMC accounting for half the variability of Gf in healthy adults (Kane, Hambrick & Conway, 2005). Theories explaining the correlation assert it to attentional control and to what extent an individual has this (Kane, Poole, Tuholski & Engle, 2006; Engle et al., 1999; Unsworth & Engle, 2007). Kane et al. (2001) have in a number of studies investigated the consequences of WM deficiencies, particularly when it relates to inhibition and attenuation of distracting stimuli.

#### *Working Memory, development and education*

Children's WMC improves gradually between the ages of 4 and 11 years (Alloway, 2006). The increase of WM ability among children occurs parallel with the maturation of the frontal lobes (Toga, Thompson & Sowell, 2006). Numerous studies have demonstrated a close association between children's performance on indicators of scholastic attainments and their WM abilities (Gathercole, Pickering, Knight, & Stegmann, 2004b; De Jong, 1998). Children with WM deficits have difficulties in handling simultaneous storage and processing. They also have greater difficulties dealing with interfering stimuli (Unsworth & Engle, 2007). There has been a debate on whether WM is merely a proxy for IQ. Recent studies, however,

indicate that differences in WM ability and achievement are still present among children with learning disabilities when IQ has been statistically controlled (Alloway, 2006, Engle et al., 1999). Gathercole et al. (2004b) showed that 7-year old children's academic success in Mathematics and English (reading and writing) was linked to success on WM related tasks. However at 14 years of age this close connection was no longer seen; instead only Mathematics and the science subjects correlated with WM. This suggests that the initial phases of learning to read are dependant on WMC (Gathercole et al., 2004b). Another study describing reading and its connection to WM showed clearly that children with reading disability performed poorly on all WM tasks measured (De Jong, 1998).

Gathercole, Pickering, Ambridge & Wearing (2004) detail the limitation in WMC of children 5 to 8 years old. They have yet to fully develop a substantial short term memory system, indications in support of this is that the phonological loop consists of the phonological store only (Gathercole & Hitch, 1993). Also, studies have shown that children of these ages use the visuospatial sketchpad part of WM to a larger extent (Rudkin et al., 2007). Older children however use the phonological loop in its entirety. Gathercole et al. (2004a) further propose that these findings suggest developmental changes in children linked to the use of strategies, a larger long-term knowledge store and also a more prominent central executive. In a review of WM (Gathercole et al., 2004a) the phonological loop and the visual sketchpad are demonstrated as two independent systems during childhood. Children with disabilities such as Foetal Alcohol Spectrum Disorder (FASD) or Down's Syndrome show prominent deficiencies in WM ability more often specifically in terms of strategy use, like active rehearsal (Loomes, Rassmussen, Pei, Manji & Andrew, 2008).

### *Training induced Improvement of WM, Attention and other Cognitive Functions*

There have been several studies investigating the potential of WM and/or attention training of children with Attention Deficit Hyperactivity Disorder (ADHD). In one early study Semrud-Clikeman, Nielsen, Clinton, Sylvester, Parle & Connor (1999) explored the effectiveness of attention training in children with ADHD using a combination of meta-cognitive and process-specific methods. The process specific methods consisted of two tasks, a visual attention task and an auditory task. The training intervention lasted for a total of 18 weeks, involving two 1-hour training sessions a week. The results of the study showed that the children who had received training improved significantly on both an untrained selective visual attention

measure and an untrained auditory divided attention measure, in contrast to a control group of children. The conclusions drawn from the study were however quite limited due to the difficulty in differentiating the contribution of the two different types of intervention (process specific and learning of strategies).

In a study by Klingberg, Forsberg and Westerberg (2002) a group of children between 7 and 15 years old with ADHD were put through a training regime consisting of repeated practice on a computerized version of a number of different tasks. The aim of the study was to investigate the possibility of improving WM through computerized, systematic practice of a number of visuospatial and verbal WM tasks. The tasks include: (1) a visuospatial WM task (2) a backward digit span (3) a letter span, and (4) a go/no go reaction time task. The difficulty was adapted on a trial-by-trial basis for each individual participant. The training program consisted of 20 minutes training a day, 4-6 days a week, for a total of 5 weeks. A control group of children used a version that differed on two accounts, (1) the difficulty levels in the tasks were not adjusted (2) the training lasted less than 10 minutes a day. The results of the study showed that the children who had received training significantly improved on both an unpractised visuo-spatial WM task and on Raven's Progressive Matrices (a nonverbal complex reasoning task) in comparison to the control group. The study thus indicated that WM capacity could be improved through training in children with ADHD (Klingberg et al., 2002). A significant limitation of the study was the modest number of participants.

This study was succeeded by a more expansive randomized, double-blind trial by Klingberg et al. (2005), conducted at four clinical sites. Both the treatment and the comparison group received training approximately 40 minutes a day, 4-6 days a week, for a total of 5 weeks. The treatment group used a version of the computerized WM tasks that automatically adjusted its difficulty levels according to the children's progress while the comparison group trained at an initial low level. The study included children aged 7 to 12 years with ADHD. The results of the study showed that children using the treatment program improved significantly in the main outcome task measuring visuo-spatial WM as well as in secondary outcome tasks measuring verbal WM, response inhibition, and complex reasoning. Furthermore, parent ratings showed significant decrease in symptoms of inattention as well as of hyperactivity/impulsivity. Hence, the results of the study show that WM can be improved by training in children with ADHD. Klingberg et al. (2005) propose that neural bases of WM

development might have some resemblance with the effects of WM training; however, the processes causing them may differ.

Olesen, Westerberg & Klingberg (2004) have also investigated the effect of WM training on healthy adults. The five week training had effects on a behavioural level and also resulted in an increased brain activity in the middle frontal gyrus and superior and inferior parietal cortices (Olesen, Westerberg, & Klingberg 2004). According to Olesen, Westerberg, & Klingberg (2004) cortical plasticity might enable WM training to affect the functional anatomical activity in prefrontal cortex. Furthermore they suggest that the cortex area affected by training could be regarded as multimodal (e.g. less stimulus specific) and that training therefore is able to influence several cognitive functions.

Furthermore, in a series of studies 4 and 6 year old children improved on tests measuring “executive attention”, or controlled attention, following a week of computerized attention training (Rueda, Rothbart, McCandliss, Saccomanno & Posner, 2005). The improvement among the children in the training group indicated an influence of age related development to the executive attention network. Their data showed that the activity in the anterior cingulate in 6 year - olds following training was more similar to the one found in adults. The children in the training groups also improved significantly on a test battery measuring intelligence, Kaufman Brief Intelligence Test; the strongest improvement being on the matrices subscale. The training period lasted for five consecutive days and consisted of nine exercises targeted at executive attention, in which difficulty increased following correct answers (Rueda et al., 2005).

In two non-randomised studies by Lee, Lu & Ko (2007) 12-year-olds improved their performance on WM tasks compared with matched controls as a result of mental abacus training (a mental arithmetic method) and music training. In the first study 16 children received abacus training for one-and-a-half hours twice a week during one year. The children performed significantly better than the matched control group on a spatial WM tasks but not on verbal WM tasks, such as digit span. In the second study 20 children who had on average 6 years of music training was compared with a matched controlled group who had not received any music training. The children in the training group out-performed the control group on both spatial and verbal WM tasks. Lee et al. (2007) suggest that the practiced skills activate WM components differently; abacus training mainly involves visuo-spatial processing while

music training engages more types of cognitive skills. When interpreting the results from these studies caution should be applied due to lack of randomisation.

### *Arousal and Performance*

To be able to attend to the correct stimuli one needs to overcome and block irrelevant distraction (Engle et al., 1999). It has been shown that performance on different cognitive tasks can be greatly impeded when distractors are prevalent (Ravelle, 1993). Moreover, what we are able to remember and process is largely affected by the attentional conditions we are subjected to (Fernandes & Moskovitch, 2000). In a series of experiments, Fernandes and Moskovitch investigated the effects of divided attention tasks upon memory retrieval processes, including verbal WM processes. The experiments showed signs of the retrieval process being disrupted when divided attention tasks were introduced; also inferring that memory performance is affected by divided attention.

In the above mentioned experiment, the distraction involved was quite resource demanding, in line with this Kane and Engle (2002) suggests that WM processing is always in competition with external and internal stimuli that disable WMC. Such stimuli could include noise, Broadbent (as cited in Baker and Holding, 1993) has conducted experiments investigating distraction upon cognitive performance, and the type of distraction he chose was white noise. Contrasting with the previous statement it has been demonstrated that noise can aid intentional recall (Smith, 1991). Noise can be regarded as an arousing element (Anderson, Ravelle & Lynch, 1984; Ravelle, 1993) not just plainly as a distractor.

The effects of arousal upon performance can be described through the Yerkes-Dodson law (Anderson et al., 1989), a curve demonstrating the relationship between performance and arousal, the shape of the curve is that of an inverted U. Performance will only be aided by arousal up to a certain point, there can both be too little arousal for optimal performance as there can be too much arousal. This emanates into a general consensus, regarding the belief that there is an optimal level of arousal on performance when conducting specific tasks (Cohen, 1980).

Linking the effects of distraction on WMC (Kane & Engle, 2002; Kane et al., 2001), to the interaction between arousal and performance (Cohen, 1980). When connecting distraction and performance it has been shown previously that a distractor such as noise can have positive

effects (Baker and Holding, 1993, Sikström & Söderlund, 2007). It has been shown in a few studies that a “moderate level of arousing stimuli” is favourable during cognitive performance (Sikström & Söderlund, 2007; Moss, Ward & Sannita, 2004). This type of arousal is derived from a statistical phenomena named stochastic resonance; an effect of noise on information transfer (Moss, Ward & Sannita, 2004).

Stochastic resonance works through a random interference (commonly known as noise) upon a nonlinear phenomenon (Moss, Ward & Sannita, 2004). The three main components of stochastic resonance consist of a threshold, noise and a sub threshold stimulus (Nagy, Gingl, Kiss & Vinko, 1995). The stimuli have to be within the detection threshold in order for the noise to be of aid. The noise thus enhances signals passing through a nonlinear system; it can be both a man-made system and a natural occurring one. It has been proven to exist in neural sensory systems in humans and non-human animals (Gammaitoni, Hänggi, Jung & Marchesoni, 1998). In humans stochastic resonance can aid neural (encoding) pathways in their detection and enhancement of weak signals. The noise will better the signal to a certain level, after which it degrades the discerning qualities and information content of the signals passing through (Benzi et al., 1981; Moss, Ward & Sannita, 2004).

The effects of noise on the human mind have been researched for many years. Broadbent, in the late 70's and Loeb in the 80's (as cited in Baker & Holding, 1993) showed in their separate studies a significant influence of noise on a Stroop test. Furthermore, Kirk and Hecht (also cited in Baker & Holding, 1993) measured an adverse effect upon vigilance tasks when the noise level was above 90 dB and a positive effect upon performance of the same task when the noise level was at 64.5 dB. Baker and Holdings (1993) review of the effects of noise on cognitive performance is concluded with a commentary of the dangers of assuming noise to be beneficial for general cognitive performance when it has clearly been shown to be very selectively positive. The type of task conducted and the level of noise are both crucial factors when determining the effects of the noise (Baker & Holding, 1993).

In a study with monkeys white noise improved performance on a spatial WM task (Carlson, Rämä, Artchakov & Linnankoski, 1997). The white noise was suggested to enhance performance by protecting against surrounding distractions. Furthermore, in study by Haller, Bartsch, Radue, Klarhofer, Seifritz, & Scheffler (2005) on adults performing a non-auditory WM task it was demonstrated that conventional fMRI noise (e.g. with a pulsed noise element) influenced brain activity differently than continuous fMRI noise (e.g. without a pulsed noise

element). Their study did not find that the different noise conditions had any effect on performance. Another review conducted by Andrew Smith (1991) on the subject of noise and attention also emphasised that noise has selective effects. Thus, the effects of noise seem to be dependent upon the specific demands of a certain task. Sikström and Söderlund (2007) have shown beneficial effects of noise upon the cognitive performance of adolescent boys with ADHD and with presumed low levels of dopamine. They argue that stochastic resonance affects moderate brain arousal. Moderate brain arousal is a theoretical model describing neuroanatomical differences in children with ADHD, pertaining to hormonal levels and releases. With reference to noise effects upon performance, the moderate brain arousal model proposes external noise to be translated into internal noise, thus heightening the otherwise reduced neural activity in children with ADHD. The model is associated to stochastic resonance in that it explains how noise can aid cognitive performance in children with presumed low levels dopamine, specifically children with ADHD. Their study pointed out that the positive effects only existed in the ADHD group not in the control group (Söderlund, Sikström & Smart, 2007).

The different studies and theories surrounding noise and cognitive performance emanated into a general hypothesis regarding the effects of noise, specifically in young school children with learning difficulties and with low academic performance. As Sikström and Söderlund (2007) showed in their studies, that white noise improves performance in children with ADHD, the effect was found in both medicated and un-medicated children (Söderlund, Sikström & Smart., 2007).

### *Aims of the Present Study*

The aims of the present study include evaluating the effectiveness of a computer software program, Memory Games (Minneslek, 2007) aimed at training WM, in children 7-10 years old. The present study's first hypothesis is that WM related tasks should be improved after completed training regime using the computer software. Moreover, the possible effects of training in a group will be investigated; an aspect never previously looked at in this context, to our knowledge. In addition the study included a second hypothesis regarding the effects of white noise on WM tasks. Our third hypothesis is that white noise will interact favourably with WM performance in children with lower cognitive performance; this is in line with previous research conducted by Sikström and Söderlund (2007).

A fourth hypothesis is that there should be an interaction effect between WM training and white noise. The children with lower cognitive performance should profit less from noise exposure when subjected to noise post training. Children with lower cognitive performance should improve their overall cognitive abilities after the computerised training, thus not needing the extra stimulus that white noise provides.

## Methods

### *Participants, selection and inclusion criteria*

The study initially included 81 children from five public elementary schools in Skåne and Stockholm, Sweden. Inclusion criteria were (1) 7 to 10 year's old, (2) access to a personal computer at school. Exclusion criteria were (1) Motor or Perceptual handicap, (2) Conduct Disorder, (3) Asperger's Syndrome, (4) Autistic Disorders and (5) Depression. All parents received a questionnaire (appendix A) asking whether their child had any of the above mentioned diagnoses. No parents, however, reported any of the above described diagnoses. The compliance criterion in the training group was a minimum of 20 days of computerised training. In the end 55 children participated for the duration of the study (see table 1.). Children were eliminated as a result of the following: (1) computer failure, (2) illness and (3) not meeting the compliance criterion. The participating children came from demographically varied areas in terms of socio-economic status and ethnicity, thus representing a varied sample of the Swedish school population. The study was approved by the Ethics Committee at Lund University (2007-11-03). Written consent was obtained from parents of the participating children.

Table 1. Subject characteristics.

	Control	Training	Total
Boys	16	14	30
Girls	17	8	25
Age, year, months (SD)	8, 1 (9.3)	8, 4 (9.8)	8,2 (9,5)
Raven's scores (M, SD)	27.8 (13.6)	27.9 (8.4)	27.9 (11.7)

The children were recruited through teachers. Initial information was given to schools verbally. Schools that expressed an interest received further details regarding the study; this was followed by a consent form sent to families of prospective children. The written information stated that not all the screened children would get an opportunity to take part in the study and that some of the included children would be part of a control group. The information also encompassed inclusion criteria, exclusion criteria and the fact that it was not part of the regular school curriculum.

### *Procedures*

All the children allowed to participate in the study were scheduled for selection tests, consisting of Raven's Standard Matrices (Raven, Raven & Court, 2004) administered in groups. The participating children were randomly assigned into two groups based on their Raven's scores; a control group and a training group. The children were also tested with a computerized digit-span task, developed for this study. The results obtained from the digit-span were deemed less reliable as a selection variable than the Raven's scores and were therefore not used.

All the participating children took part in pre-testing, after which the children in the training group commenced the five/six-week computerised training programme, using the software Memory Games. The training groups varied in size, ranging from two to eight children. Sized varied due to different conditions at the schools, some had large computer rooms, others did not. The program was distributed to the schools on a CD or incorporated onto the schools own servers. Information about the training programme was verbally presented before the training was initiated. If technical support was to be needed a software engineer was at disposal. Post-testing took place within a week after completion of the five-week training regime.

### *Apparatus*

Equipment used during pre-and post-testing included PC laptop computers with 15"4 inch widescreens. Sound was presented by the use of two channel desktop speakers, model number: OZAKI CM616.

*Pre- and post- intervention tasks*

The tasks administered during pre- and posttests were: (1) A visuospatial span board task, (2) a Stroop-like task and (3) a digit span task. All tasks were administered both before and after the intervention in the same manner. The visuospatial task and the Stroop-like task were administered with and without noise. The noise conditions were counter-balanced. These tasks were given twice in both pre- and posttesting with both noise conditions in each set of tasks. The noise was at a moderate level, approximately 69 dB, and was given through desktop speakers from a pre-recorded CD. Pink noise was used, which has in previous studies been utilized to examine the effect of SR (Söderlund, Sikström & Smart, 2007). Children were also evaluated using Teacher Rating Scale (appendix B) to examine possible behavioural changes in the children (Söderlund, 2007) during the intervention.

Descriptions of the tasks used:

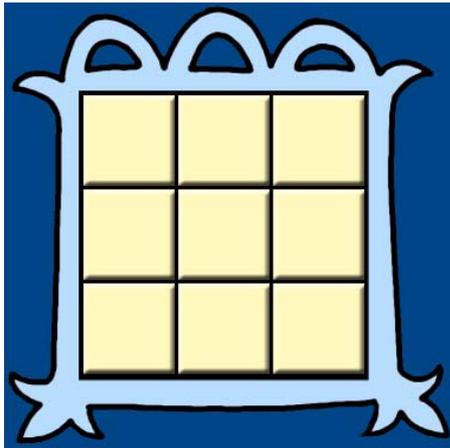
(1) *Visuospatial span-board task* – We created a VSWM task similar to tests used to measure WM development in children (Fry and Hale, 1996; Westerberg, Hirvikoski, Forsberg, & Klingberg, 2004). The task consisted of red dots that were lit up (recall stimuli) sequentially in a four-by-four grid on the computer screen. Responses were given by clicking with the mouse in the same positions as the lit up dots were presented in each of the trials. The child was able to give a response after all the recall stimuli had been displayed. The number of recall stimuli presented increased following every second trial, beginning at two and going up to nine. The task terminated when the child had failed to complete both of the two trials on a particular level.

The recall stimuli were displayed in a grid that was 13.5 x 11.5 cm. The length of each recall stimulus presentation was 900 ms, the inter-stimuli interval was 500 ms and there was a 500 ms delay before a response could be given. The children were placed approximately 40 cm from the screen during the task. All the children were presented four different stimuli series in different orders, randomly assigned over the two testing occasions. The sequences in the stimuli series were generated randomly. Performance was established for each participant by the total number of correct answers. We measured test-retest reliability by the use of Pearson correlation coefficient with the participants in the control group (n = 33) both with noise (r = 0.63), no noise (r = 0.63) and with the two conditions combined (r = 0.81).

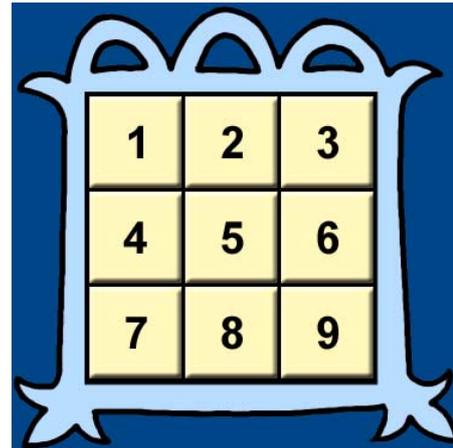
The VSWM task differed from the VSWM Memory Games exercises (see description further below) in the following aspects: (1) there was a delay in the VSWM task vs. none in exercises (2) the stimuli presented differed; circles vs. cans, animals, etc., (3) there was no sound in the VSWM task vs. music, voice in exercises (4) trials ended when an equal amount of responses as stimuli presentations had been given vs. after the first incorrect answer, (5) the stimuli is presented in a fix 4 x 4 grid vs. rotating grid, irregularly positioned grid ( $\leq 5 \times 2$ ) and stimuli in random movement.

(2) *Stroop-like task* – The original Stroop test (as cited in Baddeley, 2007) was aimed at measuring interference control and involves words expressing colours presented visually in an incongruent colour. The test does however require that the participants are able to read adequately and therefore we chose to use our own adoption of a Stroop-like task constructed by Berlin & Bohlin (2002) in which we added time as a component. Before initiating the task the child was shown the four pairs of pictures in which each pair consists of two opposites, this in order to acquaint the child with the pictures and the task. The pairs were the following: boy-girl, up-down, large-small and day-night. In the task the child was requested to as rapidly as possible name the opposite of what was presented and thereafter to click on the space button to receive the next picture. The four pairs were presented in order while the pictures within each pair were displayed in random order. The inter-stimuli time was 1000 ms and the size of the pictures on the computer screen was 8 cm x 8 cm. Performance was defined by total time to complete task measured in ms. In Berlin & Bohlin's (2002) version of the test there was a second part of the task in which the pictures are presented in a completely mixed order. We, however, in order not to exceed a total testing time of 30 minutes, administered the first part only.

(3) *Digit span task* – We created a digit span task to measure verbal WM. In the task the children were required to repeat digits first in the same order as presented and thereafter in the reverse order. In the task, digits (recall stimuli) were spoken out loud one at a time by the use of computer speakers, upon which, a visual presentation of the digits 1 to 9 was displayed on the computer screen.



Picture 1: Digits were presented through loudspeakers.



Picture 2: The digits were visually presented and the child was able to

Figure 1. Examples of layout of the computerised digit span task.

Responses were given by clicking with the mouse on the same digits that were presented out loud in each of the trials. The number of digits presented increased following every second trial, beginning at two and going up to nine. The task terminated when the child had failed to complete both of the two trials on a particular level. The digits were displayed in a grid that was 10 cm x 8.5 cm (as shown in figure 1). The time between each recall stimulus was verbally presented and the next was 1500 ms. The children were placed approximately 40 cm from the screen during the task. All the children were presented four different stimuli series in different orders. The sequences in the stimuli series were generated randomly. Performance was established for each participant by the total number of correct answers. We measured test-retest reliability by the use of Pearson correlation coefficient with the participants in the control group ( $n = 33$ ) on digit span forward ( $r = 0.74$ ) and backward ( $r = 0.65$ ) and with both tasks combined ( $r = 0.84$ ).

The backward digit span task differed from the backward digit Memory Games exercise in the following aspects: (1) no sound vs. sound in exercise, (2) trials ended when an equal amount of responses as stimuli presentations had been given vs. after the first incorrect answer.

#### *The Computerized Working Memory Intervention*

The training consisted of performing WM tasks using the computer program Memory Games (Minneslek, 2007). Along with the software a study booklet was provided and intended to facilitate the training. The program was built up on the same main principles as other

computerized WM training programs that have demonstrated a positive effect on WM capacity (Klingberg et al., 2002, Klingberg et al., 2005, Sarkar, Scanlon, & Drescher, 2007). In order to optimize training effect the program is created so that the difficulty level is continuously and automatically adapted to the performance of the child. With each correct answer the number of presented stimulus objects increase.

The computer program does however differ from other current WM training programs in some important aspects. The program does not require the child to be familiar with letters, and the graphics are specifically designed to attract and motivate the intended young age group. The program consists of a number of visuo-spatial exercises and audio-spatial exercises. The variety of WM exercises relates to two reasons: (1) the exercises are intended to focus on different components of WM and (2) their varying appearances are aimed at facilitating motivation and therefore compliance.

For this study, a specialised version of the software was created. This version consisted of four visuo-spatial exercises and three audio-spatial exercises (figure 2), where responses were given by clicking on displays using the computer mouse. In all of the exercises the participants were required to hold a number of sequentially presented objects online and then recall them in a specific order. After a number of correct trials the number of objects presented was increased. If several incorrect answers were given the difficulty level was lowered (for example one less object was presented).



*Exercise 1: Spatial sequential recognition, irregularly positioned objects*

The cans were lit up in a specific order. The participant was required to remember the order in which the cans were lit and thereafter to click on them in the same order. The participant was required to click on the cans in reverse order if a higher difficulty level was reached (i.e. if the participant has managed a number of trials with six cans presented). The position of the cans on the screen changed with each trial.



*Exercise 2: Backward digit span task, objects in a regular grid*

Digits were presented verbally. The participant was required to remember the order of the presented digits and then to click on their visual representations of the numbers in reverse order.



*Exercise 3: Spatial sequential recognition, objects in a rotating grid*

The cars lit up in a specific order in the rotating grid. The participant was required to remember the order in which the cars were lit and thereafter to click on them in the same order while the grid kept rotating.



*Exercise 4: Spatial sequential recognition, objects in a regular grid*

A lamp flashed simultaneously as an animal sound was presented, one at a time. Thereafter a picture representing one of the animal sounds was displayed in the centre. The participant was required to remember in which order the different lamp flashes/animals were presented and thereafter to click on the lamp that was connected with the animal shown in the centre.



*Exercise 5: Forward and backward colour span task, objects in a regular grid*

Colours were presented verbally. The participant was required to remember the order of the presented colours and then to click on their visual representations in the same order. The participant was required to click on the visual colour representations in reverse order if a higher difficulty level was reached.



*Exercise 6: Spatial sequential recognition, irregularly positioned objects*

The animals moved and made a sound in a specific order. The participant was required to remember the order in which the animals moved/made a sound and thereafter to click on them in the same order. The position of the animals on the screen changed with each trial.



*Exercise 7: Spatial sequential recognition, objects in random movement*

The fish moved horizontally and vertically while blowing bubbles in specific order. The participant was required to remember the order in which the fish blew bubbles and thereafter click on them in the same order. The position of the fish on the screen changed with each trial.

*Figure 2.* Presentation of the different tasks in the specialised version of Memory Games.

In the visuo-spatial exercises the aim was to remember the position of objects presented in different stimulus configurations. In the audio-spatial exercises the aim was to recall a series

of different objects. Both visual and verbal feedback was given in the computer program to maintain moment-to-moment motivation with the child during the training. To increase compliance over time the program contains a reward system, both external and internal. The external reward system included a gift or an event to happen each Friday of a completed week. Keeping track of progress and verbal cues in the computer software constitutes as the internal motivating factors.

Each day of training in the specialised version of Memory Games the children performed 70 WM trials, 10 trials per exercises. The approximated medium total training time a day was 30 minutes depending on the child's age, ability and the present difficulty level. The training took place during 25 days in a period of 5 to 6 weeks. To facilitate the computer training a study booklet was provided to each child. The booklet contained basic information about WM as well suggestions for teachers and parents on how to create a reward system for the training period. The typical layout of the computer software exercises is shown in figure 3. The exercises are varied and the design is intended to motivate children (as seen in figure 2).



*Picture 1:*

To start trial the participant clicks on the green button.



*Pictures 2 & 3:*

The stimulus objects light up in a specific order.



*Picture 4 & 5:* The participant was required to click on the stimuli in the same order as presented. If the correct sequence was completed no stimuli objects remain on the screen.

*Figure 3.* An example of a trial with two stimuli objects.

### *Statistical Analysis*

Multivariate repeated measures analysis of variance (ANOVA) was used to determine significant effects of task, noise, time and group, and the interaction between these factors.

ANOVA was also used to determine significant effects of task, software training and group size within the training group.

Significance was determined with the use of Wilks' lambda. Bivariate correlation tests (Pearson's, two-tailed) were conducted to estimate correlation between improvement in software training exercises and performance on tasks. All of the mentioned statistical procedures were conducted by the use of SPSS.

## Results

### *Results of Intervention*

The number of days between pretest and posttest testing was almost the same for the training group ( $M = 31.2$ ,  $SD = 5.03$ ) as for the control group ( $M = 32.8$   $SD = 4.04$ ).

With regards to the Stroop-like task there was no significant effect ( $p = 0.84$ ). However, in both the forward and the backward digit task ( $F(1,53) = 7.3$ ,  $p = 0.009$  vs.  $F(1,53) = 11.8$ ,  $p = 0.001$ ) there was significant improvement in the training group compared to the control group. In the non practiced VSWM task there was also a significant effect, though more modest ( $F(1,53) = 4.6$ ,  $p = 0.037$ ).

Table 2. Pretest and posttest results in control and training group using Repeated Measures ANOVA.

	<u>Control</u>				<u>Training</u>			
	Pretest Mean	SD	Posttest Mean	SD	Pretest Mean	SD	Posttest Mean	SD
Stroop-like task <sup>1,2</sup>	29,5	7,1	23,8	4,8	27,4	5,5	21,4	3,7
Forward Digit task <sup>3</sup>	20.5	8.4	19.4	8.4	22.8	7.5	26.4	8.0
Backward Digit task <sup>3</sup>	13.1	7.1	13.5	6.5	12.5	4.9	19.6	7.8
Visuo-spatial task <sup>1,3</sup>	24.0	8.6	24.9	10.2	24.7	9.1	29.2	8.7

Note: 1. Silent and noise conditions combined.

2. Time presented in seconds

3. Raw scores on the tasks.

### *Within Training Group Analysis*

The size of training group varied ( $M = 3.95$ ,  $SD = 2.08$ ) as well as the number of days trained ( $M = 21.36$ ,  $SD = 1.50$ ). The children training in pairs improved significantly more than the children training in groups of three or more on the VSWM task ( $F(1,20) = 4.4$ ,  $p = 0.048$ ). The children training in pairs however had a significantly lower pretest VSWM score and therefore we created a comparison group consisting of the 5 children with the lowest pretest VSWM scores from the training group with three or more participants to be able to further evaluate the effect of group size (see figure 4). In the forward and backward digit span task there was no significant difference between children training in pairs ( $F(1,20) = 2.7$ ,  $p = 0.119$ ) and children training in groups ( $F(1,20) = 0.06$ ,  $p = 0.813$ ). However, the results on the forward digit span task indicate a possible trend connected to the results on the VSWM task.

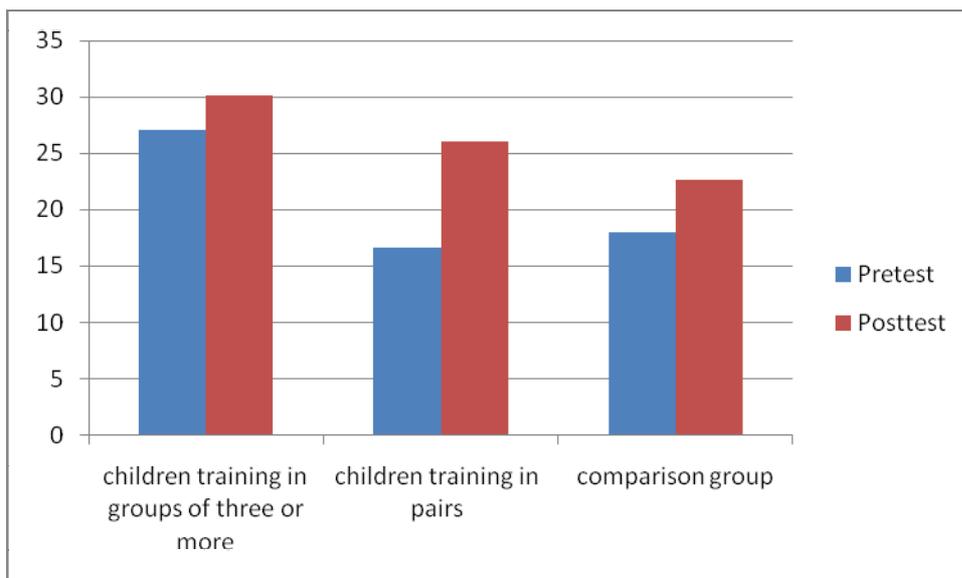


Figure 4: Improvement on VSWM task in relation to group size.

There was a significant correlation (see figure 5) between improvements in the VSWM exercises in the software and the administered VSWM task ( $p = 0.026$ ,  $R = 0.474$ ). Improvements on the VSWM task were defined by the difference in scores between pretest and posttest.

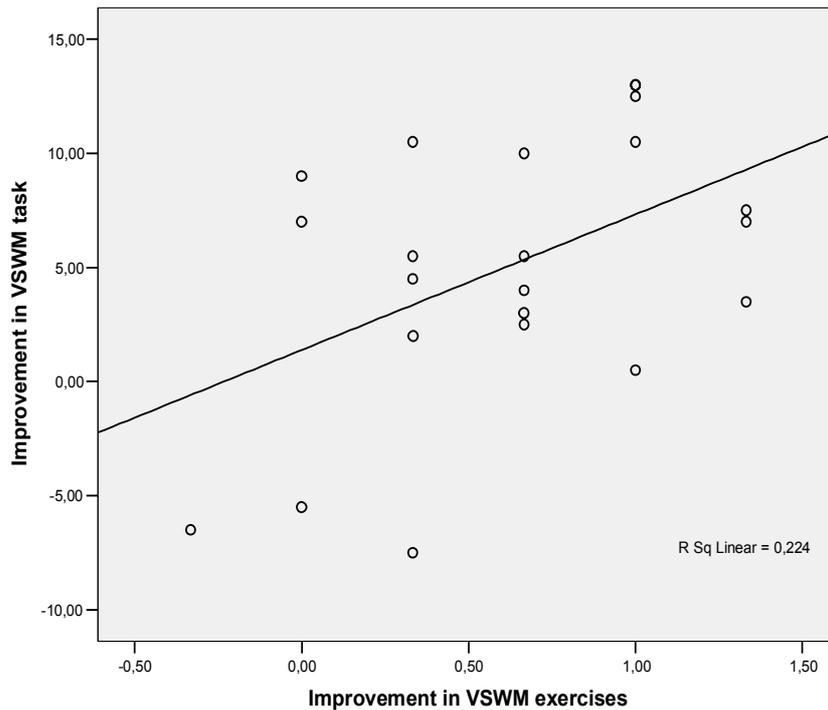
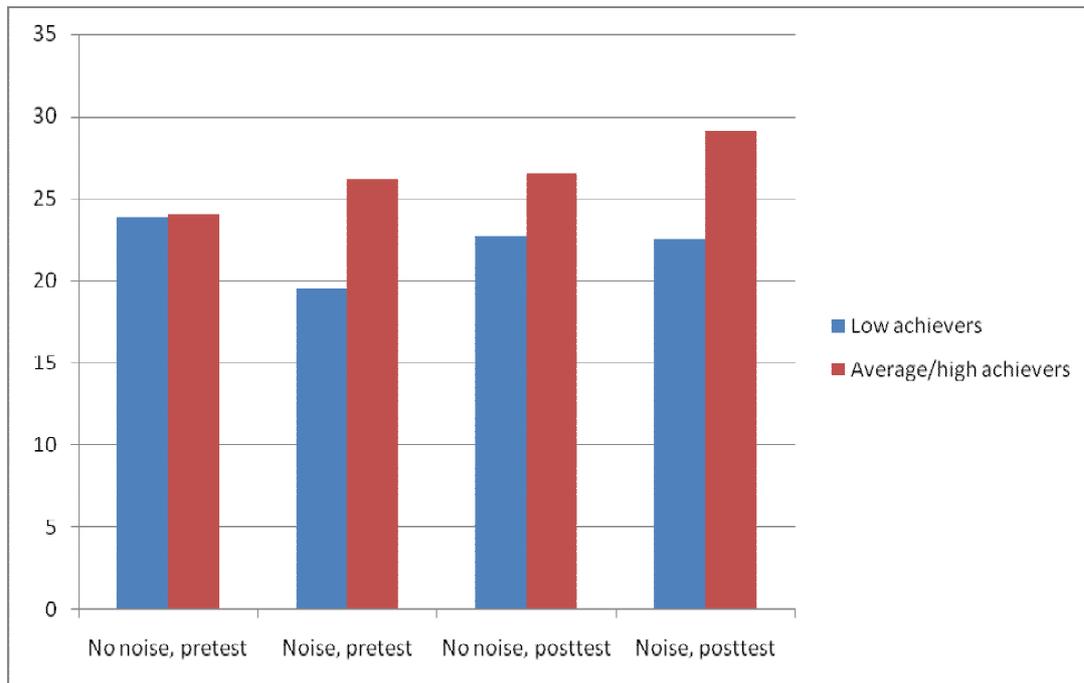


Figure 5. Scatter plot showing a positive correlation between improvements in the VSWM exercises in the software and the administered VSWM task

Improvements on the VSWM exercises in the software were defined by comparing the largest number of objects accomplished during the first five days of training compared with the last five days. VSWM training exercises 3, 6 and 7 were included in the analysis. Exercise 1 was excluded because improvement in the task resulted in stimulus presentation in reverse order. The exercise therefore became difficult to include in this analysis.

#### *Effects of noise on groups and tasks*

In the pretest there was an interaction effect of noise on the VSWM task when the participants were divided into two groups based on overall school performance rated by teachers ( $F(1,53) = 5.4, p = 0.025$ ). Noise impaired results for the low school achievers ( $n = 11$ ) while it improved results for the average/high school achievers ( $n = 36$ ). In the posttest there was no significant effect, ( $F(1,53) = 0.7, p = 0.395$ ). However, when pretest and posttest were combined the significant effect remained ( $F(1,53) = 4.8, p = 0.032$ ), for all results see figure 6.



*Figure 6.* Effects of noise on VSWM task, pretest and posttest, when children were stratified based on teachers' ratings (measured using Teacher Rating Scale (Söderlund, 2007).

An analysis was also made when children were divided into a low and high group based on Ravens scores, corrected for age using the smoothed 1998 norms for young people in France (Ravens, Ravens & Court, 2004), low group consisting of children < the 25th percentile and average/high group of children > the 25th percentile. In the pretest there was no significant effect of noise ( $F(1,53) = 0.03, p = 0.864$ ) while one was present in the posttest ( $F(1,53) = 10.7, p = 0.002$ ). There was a three-way-interaction effect on the VSWM task between group, time and noise ( $F(1,53) = 4.9, p = 0.032$ ). The two groups reacted similarly to noise in pretest while they differed in posttest (see figure 7), in which noise impaired results for the low group ( $n = 32$ ), while it improved results for the average/high group ( $n = 23$ ).

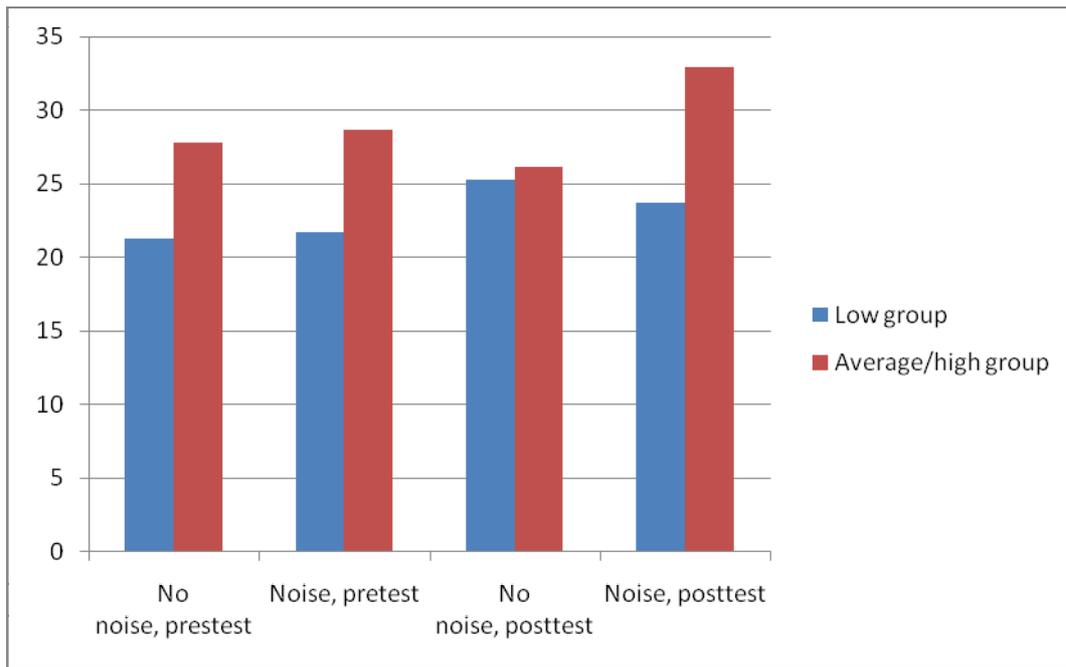


Figure 7. Pretest and posttest effects of noise on VSWM task when children divided in low and average/high group based on Raven's scores.

There was no difference on the VSWM task when comparing control and training groups reaction to noise ( $F(1,53) = 0.09$ ),  $p = 0.761$ ). On the Stroop-like task there were also no effects of noise.

## Discussion

### *Implications of the Interventions*

The study was conducted on a sample of normally developing Swedish 7-9 year-old children and does therefore differ from most previous research on computerized WM and/or attention training, which has mainly evaluated the effects on children with deficiencies or pathologies. Our main focus for investigation was positively confirmed; the computerized training of children does produce favourable results on the WM tasks. The training group improved on both a verbal and a visuospatial WM task. These results support the findings of other studies which have shown that performance on cognitive tasks can be improved by computerized interventions aimed at WM and/or attention among children (Klingberg et al., 2005; Rueda et al., 2005).

Whether the results found on the WM tasks depends on improved WMC or the development of strategies is still debatable. Previous research has shown that children between 7 and 9 years old easily learn strategies to solve cognitive problems (Gathercole, 2004a). The verbal WM task (in our case, the digit span task) closely resembled one of exercises in the software and therefore the results on this task must be considered with caution. It could indicate improved WMC or it could also indicate the development of general strategies. The visuospatial task administered did however to a larger degree differ from the exercises in the Memory Games. The inferences from the results on the VSWM task are therefore more reliable as measures of improvement. There were no significant differences between training and control group on the task used to measure inhibitory control, the Stroop-like task. This could either be viewed as an indication of the fact that WMC was not influenced by training or that the adaptation of the task we used was unsuitable for the participating sample group.

The within group analyses showed significant results concerning the influence of group size on VSWM task performance while it had none on verbal WM performance. The results of the study have thus given us strong indications that computerized WM training in group is far from optimal, especially when training visuo-spatial WM. The difference in results could be due to differences in attentional strain for the two types of tasks. The verbal WM task involved familiar objects (e.g. digits, colours) that could be quite easily rehearsed with the use of the phonological loop (Baddeley, 2000; Gathercole, 1994). The VSWM tasks on the other hand to a larger extent involved unfamiliar objects and even new visual stimuli, which therefore had to be maintained by intensive and continued attention. VSWM might be more attention demanding than verbal WM (Baddeley, 2000) and could therefore be more affected by surrounding disturbances during training. Furthermore it is possible that it is easier to develop strategies on verbal WM tasks than there is on visuospatial WM tasks. Children of these ages are quite prone to the use of strategies to compensate for lack of memory storage (Gathercole, 2004) and it is therefore also possible that the training group during the intervention period had time to develop strategies. We also found a positive correlation between improvement on the VSWM exercises and improvement on the VSWM task, this further indicating that merely exposure to VSWM exercises is not enough to improve performance on VSWM tasks. Thus implying that the computer software had a positive effect on the children's VSWM.

Training in group proved to be a complex situation. One can speculate on all the possible implications of children sitting together. It could be as simple as being far too distracting and

therefore inhibiting attention allocation. The noise level inevitably rises the more people are in a room together and thus creates an unsuitable environment for cognitively straining activities; such as WM training. Furthermore, the motivational aspect in the intervention with the study booklet and verbal encouragement from the training supervisor is naturally diminished the more children one supervisor is in charge of. The motivational aspect is key, partially due to the fact that the children maximize their WMC, an aspect already investigated to be the most efficient way of training WM (Klingberg et al., 2005). Possibly the children may find it difficult to handle the demands of the exercises on their own, which could imply that motivating the child is crucial. To enable successful results of computerized WM training it is likely that motivation needs to be attended to properly, and that the amount of distraction surrounding the training should be kept at a minimum.

Some of the most compelling results found in this study came from the interaction of noise and group on the visuospatial WM task. Contrasting to previous findings, in which noise has had positive effects on cognitive performance in children with presumed low dopamine, comparable to the low performers in the present study (Söderlund, Sikström & Smart, 2007; Sikström et al., 2007), the low performing group did not improve their performance on the visuo-spatial WM task during noise exposure. However, noise had a positive influence on the performance of high achievers. It has been demonstrated that noise has an arousing effect on cognitive performance (Smith, 1991; Baker & Holding, 1993) and that it can narrow the attentional field, thereby facilitating the individual's capability to focus (Cohen, 1980). It is plausible that the noise level presented during the visuospatial task was suitable for high achievers and therefore heightened their level of attention. Previous studies examining the effects of noise upon cognitive performance can also shed light on the findings of this study; Baker and Holding (1993) revealed the old findings of Broadbents', that noise of 64 dB had positive effects on performance. Söderlund, Sikström & Smart's (2007) found that noise of 80 dB improve cognitive performance in children with presumed low dopamine level. Therefore, children with presumed higher levels of dopamine, such as high performers may be better suited to the lower dB level. They were in our own study, favourably aroused by the 68 dB when conducting the VSWM task, thus performing better than without the arousing stimulus.

### *In Contrast to Similar Studies*

Studies have demonstrated that cognitive abilities can be trained and improved by systematic interventions aimed at improving WM and/or attention (Klingberg et al., 2005; Westerberg et al., 2004; Klingberg et al., 2002; Rueda et al., 2005; Semrud-Clikeman et al., 1999). However, the majority of studies conducted have included individuals with deficiencies or pathologies. The present study does on this point stand apart by including solely a sample of normally developing Swedish 7-9 year-old children. As in previous studies, improvement was found on verbal and visuospatial WM tasks (Klingberg et al., 2005; Westerberg et al., 2004; Klingberg et al., 2002). In these studies, transfer effects were also evident as a result of WM training on a task measuring inhibitory control, such effects were however not found in the present study.

### *Limitations*

A limitation of the study was the modest number of participants. As always, a larger population is to prefer for the statistical relationships to be reliable and generalizable. Furthermore, it would have been possible to more thoroughly evaluate the effects of training if more measures of WM had been included.

The inhibitory measure we used to examine WM improvement was a child-adjusted Stroop-like task (Berlin & Bohlin, 2002), which we altered slightly by adding reaction time and excluding the completely randomized section. In hindsight, the randomized part of the Stroop-like task could have shed more light on the effects of WM training and also how performance varies in the two noise conditions. Moreover, the digit-span task and the VSWM task were constructed especially for this study. Therefore, further studies are necessary to thoroughly establish their reliability and validity.

The effects of noise would have been able to be more comprehensively analyzed if more noise levels had been included.

### *Conclusions*

The study revealed several findings. Firstly, computerized WM training improved performance on verbal and visuospatial WM tasks. Secondly, training and group size

influenced the improvement on a visuospatial WM task more than on a verbal WM task. Thirdly, the results of the study gave us indications that computerized WM training in group of more than two children is not favourable, particularly when visuospatial WM tasks are included in the training regime. Finally, white noise improved the results of average/high school achievers on a visuospatial WM task while it did not for low school achievers. The level of noise on the VSWM task used in the present study might have successfully aroused the average/high school achievers and therefore facilitated attention and hence improved performance.

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## Appendix A

Hälsöformulär  
**Arbetsminnesträning med Minneslek**

Vårdnadshavarens/förälderns namn	<input type="text"/>
Barnets namn	<input type="text"/>
Skola	<input type="text"/>
Stad	<input type="text"/>
Har ditt barn större svårigheter med något av följande?	
Med motoriken	JA <input type="checkbox"/> NEJ <input type="checkbox"/>
Med synen	JA <input type="checkbox"/> NEJ <input type="checkbox"/>
Medicin	
Tar ditt barn medicin regelbundet?	JA <input type="checkbox"/> NEJ <input type="checkbox"/>
Vilken?	<input type="text"/>
För vad? (vilka symptom, besvär)	<input type="text"/>
Har ditt barn någon av följande diagnoser?	
Asperberger syndrom	JA <input type="checkbox"/> NEJ <input type="checkbox"/>
Uppförande störning	JA <input type="checkbox"/> NEJ <input type="checkbox"/>
Autistiskt syndrom	JA <input type="checkbox"/> NEJ <input type="checkbox"/>
Depression	JA <input type="checkbox"/> NEJ <input type="checkbox"/>

Om du skulle ha några frågor går det bra att ringa följande nummer nedan. Om ingen svarar lämna ett meddelande på telefonsvararen så ringer vi upp.

Tack för att du har valt att fylla i.

Med vänliga hälsningar

Psykologkandidater

Anna Backman

Erik Truedsson

Tel: 0733-450982 (Erik)

0732-445857 (Anna)

**Appendix B**

**ARBETSMINNESTRÄNING**

Skola:

Lärares namn:

Kodnummer:

Kön:

Ålder:

*Ringa in det som bäst passar in:*

**I.** Bedömning av skolprestation: (av vad som är normalt för åldern)

över medel = 3

medel = 2

under medel = 1

Ev. Lärarkommentar:

**II.** Dyslexi 1...2...3...4...5...6...7 Läser och skriver bra (för sin ålder)

Ev. Lärarkommentar:

**III.** Motorisk oro:

**Beteende A:**

Har ytterst svårt att sitta still under lektionerna. Eleven rör sig oroligt i bänken eller vill gärna röra sig omkring i klassrummet även under lektionstid. Kan också vara pratig och högljudd.

### **Beteende B:**

Eleven har inga som helst svårigheter att underordna sig, till och med höga krav på stillhet och tystnad.

De flesta barn befinner sig mellan dessa båda yttervärden.

Liknar A 1.....2.....3.....4.....5.....6.....7 Liknar B

## **IV. Koncentration:**

### **Beteende A:**

Eleven kan inte samla sig inför förelagt arbete utan sysslar med ovidkommande saker eller sitter och hänger eller "drömmer". För några ögonblick kan de ägna sig åt uppgiften men låter sig strax fångas av ovidkommande händelser eller tankar. De ger i allmänhet snabbt upp även om arbetet är avpassat efter deras begåvningsnivå.

### **Beteende B:**

Eleven har en utpräglad förmåga att fördjupa sig i en uppgift och arbeta koncentrerat. Låter sig aldrig distraheras och ger inte heller upp arbetet med en uppgift som passar deras begåvningsnivå.

Det är vanligast att barn befinner sig mellan dessa ytterligheter.

Liknar A 1.....2.....3.....4.....5.....6.....7 Liknar B