Elements of Working Memory as Predictors of Goal-Setting Skills in Children With Attention-Deficit/Hyperactivity Disorder

Anna Nyman1, Taina Taskinen1, Matti Grönroos1, Leena Haataja1, Jaana Lähdetie1, and Tapio Korhonen1

Abstract
The aim of the study was to examine how goal-setting skills of children with attention-deficit/hyperactivity disorder (ADHD) can be predicted with elements of working memory. The study involved 30 children with an ADHD diagnosis and 30 healthy volunteers. The IQ of the participants was assessed, and ADHD symptoms were evaluated by parents. Each of the elements of working memory was assessed with two measures as well as goal-setting skills. In the tests of the central executive and in one of the tests of the visuospatial sketch pad, children with ADHD performed more poorly than controls but not in the tests of the phonological loop. Children with ADHD performed more poorly than controls did on the mastery scores of the goal-setting measures but not on the Strategy scores. According to regression analysis, central executive functions are critical for the variance in goal-setting skills in children with ADHD.

Keywords
ADHD, working memory, goal setting, children

Working memory is regarded as a permanent trait of the individual (Conway, Kane, & Engle, 2003; Kyllonen & Christal, 1990) underlying other cognitive abilities such as goal-directed behavior and goal-setting skills (Barkley, 1997). When performing complex tasks, it is necessary to temporarily store and process information in the working memory to complete the task (Baddeley, 1996).

Attention-deficit/hyperactivity disorder (ADHD) is characterized by inattention, impulsivity, and hyperactivity (American Psychiatric Association, 1994). ADHD is frequently associated with low academic performance, and children with ADHD have increased risk of learning disabilities. Among the theories of ADHD (e.g., Pennington & Ozonoff, 1996; Sergeant, Oosterlaan, & van der Meere, 1999; Sonuga-Barke, 2002), Barkley’s (1997) causal executive dysfunction theory of ADHD highlights the role of working memory as one of the main executive functions creating goal-directed behavior and further effective self-regulation and adaptive functioning. Working memory is of central importance among the deficits in executive functions that neuropsychological studies consistently report in ADHD (for reviews, see Holmes et al., 2010; Tannock, 1998; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). In Barkley’s model, working memory is held responsible not only for keeping stimuli in mind but also for allowing goal-directed behavior.

Working memory is not a unitary concept, and the terminology of working memory is not convergent. Some researchers (Daneman & Carpenter, 1980) separate short-term memory and working memory. Short-term memory refers to passive storing and working memory to active processing of information. Others (Baddeley, 1986) integrate these functions and use only the concept of working memory. In this study, Baddeley’s (1986) multicomponent model of working memory is used to clarify more precisely the storing and processing functions of working memory in children with ADHD. In this model, at least three elements are thought to be essential for working memory function. The phonological loop is specialized in the temporary storage of phonological information and the visuospatial sketch pad in the temporary storage of visuospatial information. The central executive is

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involved in the control and regulation of the working memory system. It coordinates the phonological loop and the visuospatial sketch pad, controlling attention rather than storing information. Despite its important role, the functioning of the central executive is the least understood component of working memory. The three suggested main functions of the central executive are switching, updating, and inhibition (Dehn, 2008; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). To explain the influence of long-term memory on the contents of working memory, Baddeley (2000) recently added to this model a fourth subcomponent, the episodic buffer, but its function is not very well known. Recent evidence shows that children with ADHD present difficulties in working memory already at the early age of 5 years (Re, De Franchis, & Cornoldi, 2010).

**Working Memory in Children With ADHD**

Previous studies have suggested that children with ADHD had no deficits in the function of the phonological loop (Karatekin, 2004; Karatekin & Asarnow, 1998; Mariani & Barkley, 1997), which is commonly assessed with digit span or word recall tasks. On the other hand, a recent review reveals growing evidence of deficits in the ability to maintain and manipulate visuospatial information (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005). The findings are, however, inconsistent. One possible reason for this is the wide range of visuospatial tests used in studies where visuospatial working memory in children with ADHD has been assessed (Karatekin, 2004; Mariani & Barkley, 1997; Martinussen & Tannock, 2006; Westerberg, Hirvikoski, Forssberg, & Klingberg, 2004). In Brocki, Randall, Bohlin, and Kerns (2008) it was suggested that it is the variation in terms of difficulty level or load on the central executive rather than the variation in modality that is important in demonstrating working memory deficits in ADHD. Isolating the visuospatial sketch pad component using neuropsychological tests has proven difficult because of the requirement to present material that can be coded only in visuospatial form. Two tasks that are thought to meet this criterion are the Corsi Blocks Test (e.g., Milner, 1971) and the Visuo-Spatial Test (e.g., Della Sala, Gray, Baddeley, Allamano, & Wilson, 1999).

Research findings are consistent concerning central executive problems in ADHD. Children with ADHD tend to perform poorly in complex working memory tasks that heavily rely on the central executive. For example, they perform more poorly than controls on the Digits Backward Test (Mariani & Barkley, 1997; Rosenthal, Riccio, Gsanger, & Jarratt, 2006), which involves the capacity to hold and manipulate information. Another measure that according to Baddeley (2002) heavily relies on the central executive is the Dual Task condition, where the capacity to coordinate performance on two separate tasks is needed. There are only a few studies on Dual Task performance in ADHD, and the results are partly conflicting. West, Houghton, Douglas, and Whiting (2002) found no group difference between controls and children with ADHD using visual search and auditory signal counting as the two tasks. Karatekin (2004) reported longer reaction times in Dual Task performance in children with ADHD compared to controls when a simple reaction time task was combined with the digit span task, with the length of lists set at the child’s own span. Until recently, the central executive tasks in use suitable for children, such as complex span tasks, have been exclusively verbal in nature. Re et al. (2010) recently found that children with ADHD also had deficits in central executive assessed with the Dual Request Selective Task, requiring central executive and visuospatial sketch pad functions. Alloway, Gathercole, and Pickering (2006) assessed central executive functions with both visuospatial and verbal tasks. The results indicate that children aged 4 to 6 years draw more on central executive than older children when performing visuospatial sketch pad tasks. Otherwise central executive capacity was suggested to be primarily driven by a domain-general mechanism. This finding is in line with Baddeley’s (1986) multicomponent model of working memory.

**Goal-Setting Skills in Children With ADHD**

Executive functions are higher level cognitive processes required in goal-directed behavior. A precise definition of executive function is, however, still lacking, although most investigators would agree that executive functions are self-regulatory functions incorporating the ability to inhibit, shift, set, plan, organize, use working memory, problem solve, and maintain a set for future goals (Seidman, 2006). Usually goal-setting skills refer to the ability to develop new initiatives and concepts as well as the capacity to plan actions in advance and approach tasks in an efficient and strategic manner (P. Anderson, 2002). Deficits in planning and organization are quite well documented in children with ADHD (Tannock, 1998; Willicutt et al., 2005). Still, there are only a few measures that meet these demands (Gioia et al., 2002). The Wisconsin Card Sorting Test (Heaton et al., 1993), the Tower of Hanoi (Welsh, Pennington, & Grossier, 1991), and the Rey Osterrieth Complex Figure Test (ROCFT; Rey, 1941) are among the most commonly used. In our study we focused on the goal-setting aspect of executive functions and limited our assessment to planning and organization measures following the reasoning and assessment methods used by V. Anderson, Anderson, Northam, Jacobs, and Catroppa (2001); P. Anderson (2002); and V. Anderson and Catroppa (2005).

Children with ADHD have been shown to have disabilities in goal-setting skills. Assessment of goal-setting skills is complicated by the multifactorial nature of measures purported to evaluate these skills as well as the different scoring systems used. In the present study, goal-setting skills are assessed with the Tower Test (NEPSY, a Developmental Neuropsychological
Aims of the Present Study

The aim of the present study was to assess working memory and goal-setting skills in school-aged children with ADHD and to assess the relationship between working memory and goal-setting performances. We have focused on working memory assessed within Baddeley’s framework and goal-setting skills assessed with complex neuropsychological measures.

Method

Participants

The study involved two groups of children (8–10 years of age): 30 children with an ADHD diagnosis and 30 healthy volunteers closely matched to the ADHD group by age, gender, and parental education (Table 1). The children with ADHD were recruited from the referrals from the Outpatient Ward of Paediatric Neurology of the Turku University Hospital, Finland. They were diagnosed at the unit for pediatric neurology according to the criteria as presented in the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 1994). All children in the ADHD group fulfilled the criteria of the combined subtype. Exclusion criteria for the ADHD group were (a) any other neurological diagnosis, (b) any psychiatric diagnosis, and (c) any need for special education because of learning disorders. Nine children in the ADHD group were on stimulant medication before they were recruited. The medication was temporarily interrupted for 24 hr before the test situation. The control participants were recruited from local schools in Turku. Teachers randomly selected 10 pupils from their classes, children who did not have any learning problems or had not needed special educational assistance. The teachers knew the pupils well enough to evaluate possible learning and behavioral problems. The families of the children were contacted by mail and asked for their consent for the child’s participation. The letter included information on the study and a consent form with questions including details of parental education and the birth date of the child. Among the consenting candidates, three children per class were selected for the control group, based on gender, age, and parental education. The IQ of the children with ADHD and the control children was estimated using a short scale of the Wechsler Intelligence Scale for Children–Third Edition (WISC-III; Sattler, 2001; Wechsler, 1991; Table 1). Only children with an overall estimated IQ greater than or equal to 80 were recruited. No significant difference in age, gender, or parental education was found between the two groups. A significant group

<table>
<thead>
<tr>
<th>Measure</th>
<th>ADHD (n = 30)</th>
<th>Control (n = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>8.67</td>
<td>0.80</td>
</tr>
<tr>
<td>Boys (%)</td>
<td>83.3</td>
<td>9.1</td>
</tr>
<tr>
<td>WISC-III Short Scale IQ</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>94.70</td>
<td>12.77</td>
</tr>
<tr>
<td>Education: Mother</td>
<td>M</td>
<td>SD</td>
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<tr>
<td></td>
<td>1.86</td>
<td>0.45</td>
</tr>
<tr>
<td>Education: Father</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>1.92</td>
<td>0.55</td>
</tr>
<tr>
<td>ADHD symptoms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total score</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>34.083</td>
<td>9.22</td>
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<tr>
<td>Hyperactivity/Impulsivity</td>
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<td>SD</td>
</tr>
<tr>
<td></td>
<td>17.76</td>
<td>5.15</td>
</tr>
<tr>
<td>Inattention</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>16.47</td>
<td>4.68</td>
</tr>
</tbody>
</table>


Previous findings, as well as Barkley’s (1997) causal executive dysfunction theory, suggest that goal-setting skills require working memory (Humes et al., 1997; Levin et al., 1996). Sonuga-Barke, Dalen, Daley, and Remington (2002) found some evidence for a structural relation between planning and working memory in preschool children with ADHD, when planning was assessed with the TOL and working memory with the Noisy Book Task adapted for preschoolers (Hughes, 1998). Klingberg, Forssberg, and Westerberg (2002) found that intensive training with computerized working memory tasks also improved goal-setting skills, more specifically problem solving. Improvement was evident both for the control group and for children with ADHD. However, the exact nature of the connection between elements of working memory within Baddeley’s framework and goal-setting skills is still unclear.

Table 1. Description of the ADHD and Control Groups
difference existed for the estimated IQ ($t = -3.760, p < .001$). Parent rating scales of the core ADHD symptoms (DuPaul et al., 1998) differed significantly between the groups (Total score $t = 14.691, p < .001$; Hyperactivity/Impulsivity $t = 16.119, p < .001$; Inattention $t = 13.891, p < .016$; Table 1).

**Procedure**

Each child with ADHD was individually tested in the hospital. A short-scale WISC-III was performed on the child during the first session. At the second session, working memory and goal-setting measures were examined. Each session lasted approximately 1 hr. All tests were carried out in the same order for all children. Each child in the control group was tested individually in two sessions during the same day at school. The Ethics Committee of the Hospital District of Southwest Finland approved the study.

**Measures**

**Working Memory.** Each of the elements of working memory (Baddeley, 1986) was assessed using two measures.

**Phonological unit.** The Digits Forward (WISC-III; Wechsler, 1991) score represents the highest number of digits repeated in correct order. The Word Recall (NEPSY, a Child Neuropsychological Assessment; Korkman et al., 1998) score represents the highest number of words repeated in correct order.

**Visuospatial sketch pad.** The Corsi Blocks (Milner, 1971) score represents the longest correctly recalled sequence of tapped blocks. In the Visuo-Spatial Test (modified from Wilson, Scott, & Power, 1987), the child was shown a filled matrix for 3 s and then asked to fill in the correct cells of an empty matrix. The score is the maximum number of filled cells in the matrix that can be remembered.

**Central executive.** The Digits Backward (WISC-III; Wechsler, 1991) score represents the highest number of digits repeated backward. The Dual Task Response Time (RT) Test was adapted from Karatekin (2004) and McDowell, Whyte, and D’Esposito (1997). In the first condition, children pressed a button when they saw a square appear on a computer screen (baseline). In the Dual Task condition, the baseline task was combined with a secondary task to assess Dual Task performance. In the secondary task, the examiner read out loud sequences of random digits at the child’s own digit span and asked the child to repeat the digits in the same order. The used span equaled the number he or she could correctly repeat twice in a row. The children were instructed to continue pressing the button as quickly as possible while performing the secondary task. The experiment was performed using Presentation software (Version 9.13; www.neuro-bs.com) according to Karatekin (2004).

**Goal-Setting Skills.** By goal-setting skills we refer to the type of skills needed in performance of the two goal-setting measures; Tower Test (NEPSY, Korkman et al., 1998) and the ROCFT (Rey, 1941). The Tower Test is an adaptation of Shallice’s (1982) TOL and makes use of three balls (yellow, red, green) that can be placed on pegs of three heights (short, medium, long). The children were required to match the balls according to the examiner’s stimulus booklet in a prescribed number of moves. There were a total of 20 problems (maximum 20 points), graded in difficulty according to complexity and the number of moves (1–7). The time limit was 45 s. Total Outcome equals the number of correct responses that the child manages to reproduce at the first attempt, and it represents the mastery of the skill. Two other scores reflect the used strategy. Solution Time refers to the time needed to execute the pattern in the prescribed number of moves. The implementation instructions were modified according to P. Anderson, Anderson, and Lajoie (1996) to get more information about the goal-setting strategy: When a child failed to complete an item, the balls were repositioned in the original configuration and the child had the opportunity to try again. The third measure used was Number of Attempts. This refers to the number of attempts the child needs to make before achieving correct configuration in the prescribed number of moves in 45 s.

In the ROCFT (Rey, 1941) the children were asked to copy a complex line drawing, using a series of colored pencils. The time interval per color was 30 s. Two scoring principles were applied. The mastery of the test was evaluated and scored according to Lezak (1995), generating an Accuracy score. In addition, an Organizational score was derived to evaluate the solution strategies of the participants, based on the rating devised by V. Anderson et al. (2001), and provided an organizational rating between 1 (unrecognizable) and 7 (excellent organization). The first author scored all of the ROCFT drawings, and for purposes of reliability two other raters scored 50% of the drawings each. The interclass correlation coefficients across all three raters varied from $r = .892$ to $r = .907$ ($p < .001$).

**Statistical Analyses**

To determine the group differences in the background variables and in working memory and the goal-setting measures, $t$ tests were performed. The group comparisons were also repeated (ANCOVA) with IQ as a covariate. For purposes of regression analysis, $z$ score transformations of raw scores for working memory and goal-setting measures were used. The Dual Task RT scores were multiplied by $-1$ to transform the variable. Sum variables for the three working memory units were calculated by adding the two variables representing each element of working memory. To calculate a sum variable for goal-setting skills, the Rey Accuracy and Tower Total Outcome mastery scores were added together. Regression analyses were conducted to examine whether there were significant interactions between group membership (ADHD vs. control
group) and elements of working memory (phonological loop, visuospatial sketch pad, central executive), group membership and IQ, and group membership and age in the goal-setting skills. Nonsignificant interaction terms were dropped one by one from the model, so the final model included only significant interaction terms. Significant interactions were further examined by testing the significance of the regression coefficients (Bs) separately for the ADHD and control groups.

Results

Group Comparisons

In the phonological loop tests the groups performed similarly (Table 2). In tests of the visuospatial sketch pad, children with ADHD performed more poorly than the controls on the Visuo-Spatial Test ($t = -2.678, p = .010$) but not on the Corsi Blocks. Group differences were also found in the function of the central executive. The children with ADHD repeated fewer digits than the controls in Digits Backward ($t = -2.868, p = .006$). Before the group comparisons in the Dual Task Test (baseline and Dual Task condition), RTs less than 80 ms and more than 2 standard deviations above the child’s mean were eliminated. There were no differences in the number of eliminated trials in the baseline condition in anticipatory responses (ADHD: $M = 0.20, SD = 0.48$; controls: $M = 0.30, SD = 0.75$) or in slow responses (ADHD: $M = 2.67, SD = 0.96$; controls: $M = 2.40, SD = 1.20$). No group differences were found in the Dual Task condition in anticipatory responses (ADHD: $M = 0.053, SD = 0.82$; controls: $M = 0.33, SD = 0.76$) or in slow responses (ADHD: $M = 2.80, SD = 1.24$; controls: $M = 3.00, SD = 1.11$). The children with ADHD had longer RTs than controls in the Dual Task condition (ADHD: $M = 1011.54, SD = 683.61$; controls: $M = 674.89, SD = 164.00; t = 2.623, p = .011$), which required the central executive. RTs in both groups were similar in the baseline condition (ADHD: $M = 522.57, SD = 161.10$; controls: $M = 674.90, SD = 113.47$), suggesting that the group difference in the Dual Task condition is not explained by differences in the response speed. There were no group difference in digits repeated correctly during the Dual Task condition (ADHD: $M = 0.30, SD = 0.96$; controls: $M = 0.22, SD = 1.11$).

The children with ADHD had lower Accuracy scores in the ROCFT than the controls ($t = -2.671, p = .010$), and they got lower Total Outcome scores in the Tower Test than the controls ($t = -1.997, p = .050$). No group differences were found in the strategy measures. However, when the results were reanalyzed with IQ as a covariate (ANCOVA), the significant group differences disappeared.

Regression Analysis

Regression analyses were conducted to find a model explaining the goal-setting skills in each group. The composed model, $F(7, 52) = 5.89, p < .001$, indicated that 36.7% (adjusted $R^2$) of the variance in goal-setting skills was explained by this model. All of the working memory units were included in the model and were significant at the level of 5%. Short-scale IQ and age were not significant predictors and thus were dropped.
from the final model. Significant interactions were further examined by testing the significance of the regression coefficients ($B$s) separately for the ADHD and the control group (Table 3). Results suggest that in children with ADHD central executive functions predict goal-setting skills. Phonological loop and visuospatial sketch pad performances seem to predict goal-setting skills in the control group.

**Discussion**

The aim of this study was to explore working memory and goal-setting skills in children with ADHD as well as to study whether working memory predicts goal-setting skills as proposed by Barkley’s (1997) causal dysfunction theory of ADHD. More specifically, we studied the roles of different elements of working memory (Baddeley, 1986) in predicting goal-setting skills. Our results suggest that working memory is one of the executive functions needed in goal setting but that there are differences between children with ADHD and typically developed children as to which components of working memory predict goal-setting skills.

**Group Comparisons**

In general, children with ADHD did not differ from controls in the phonological loop measures. This is consistent with the results of several earlier studies showing that deficits in the phonological loop are not characteristic of children with ADHD (Karatekin, 2004; Karatekin & Asarnow, 1998; Mariani & Barkley, 1997). Group differences were found only partly in the test performances requiring the visuospatial sketch pad, even though there is growing evidence of deficits in the ability to maintain and manipulate visuospatial information in children with ADHD (Martinussen et al., 2005). In the *Visuo-Spatial Test*, the children with ADHD managed to fill fewer cells in the matrix than the controls, but in the *Corsi Blocks*, no group difference was found in the maximum span. It is suggested that the visuospatial sketch pad might be more closely associated with the central executive than is the phonological loop (Gathercole & Pickering, 2000). The complexity of the *Visuo-Spatial Test* may set more demands on the central executive compared to the simpler *Corsi Blocks*. Our results and previous conflicting findings about deficits in the visuospatial storage of children with ADHD may reflect some deficits in the function of the central executive instead of, or in addition to, deficits in the visuospatial sketch pad. However, the exact nature of these differences remains unknown.

The results concerning the central executive were consistent with earlier studies indicating that, as a group, children with ADHD tend to perform poorly on complex working memory tasks, which rely heavily on the central executive (Mariani & Barkley, 1997; Rosenthal et al., 2006). In this study, group differences were found in performances in the Digits Backward and the Dual Task condition, indicating that children with ADHD had problems in the central executive compared to the typically developed control children. They repeated fewer digits backward than control children did. In the Dual Task condition they showed longer RTs than controls when performing two tasks concurrently, a finding that is similar to the results of Karatekin (2004).

Results concerning the goal-setting skills of children with ADHD in this study appeared to be complex. Children with ADHD had problems in higher order skills at the overall level of goal setting as shown by the results of ROCFT Accuracy and Tower Total Outcome. The Tower Total Outcome result is consistent with previous findings (Kempton et al., 1999, Marzocchi et al., 2008; Nigg et al., 2002), but the Rey Accuracy result differs from most results of earlier studies (McGee, Williams, Moffitt, & Anderson, 1989; Moffitt & Silva, 1988).

In the present study, children with ADHD had no problems with lower order strategy skills in goal setting (ROCFT Organization, Tower Solution Time, and Failed Attempts). Other studies have also shown negative results (ROCFT: Wu et al., 2002, TOL: Sami et al., 2003), but problems with strategy have also been found in participants with ADHD (TOL: Kempton et al., 1999; Marzocchi et al., 2008; ROCFT: Seidman et al., 1995). Even if some of the inconsistencies may be related to the different scoring systems used in ROCFT or different Tower-type versions used, it seems justifiable to conclude that in children with ADHD there is a wide variation in goal-setting strategies as measured by these tests.

**Regression Analysis**

According to the model predicting goal-setting skills, there are differences between children with ADHD and typically developed children as to which parts of working memory are critical in goal-setting situations. In controls, the goal-setting skills seem to be predicted by the visuospatial sketch pad and

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**Table 3. Regression Model With Three Variables Predicting Goal Setting**

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE(B)</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADHD Phonological loop</td>
<td>.28</td>
<td>.18</td>
<td>1.57</td>
</tr>
<tr>
<td>Visuospatial sketch pad</td>
<td>-.04</td>
<td>.16</td>
<td>-0.25</td>
</tr>
<tr>
<td>Central executive</td>
<td>.37</td>
<td>.15</td>
<td>2.54*</td>
</tr>
<tr>
<td>Control Phonological loop</td>
<td>.26</td>
<td>.13</td>
<td>2.00*</td>
</tr>
<tr>
<td>Visuospatial sketch pad</td>
<td>.61</td>
<td>.17</td>
<td>3.58**</td>
</tr>
<tr>
<td>Central executive</td>
<td>-.22</td>
<td>.27</td>
<td>-0.83</td>
</tr>
</tbody>
</table>

Goal setting = Rey Osterrieth Complex Figure Test Accuracy + Tower Total Outcome; phonological loop = Digits Forward + Word Recall; visuospatial sketch pad = Corsi Blocks + Visuo-Spatial Test; central executive = Digits Forward + Dual Task Reaction Time.

*p < .05. **p < .01.

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**Regression Analysis**

According to the model predicting goal-setting skills, there are differences between children with ADHD and typically developed children as to which parts of working memory are critical in goal-setting situations. In controls, the goal-setting skills seem to be predicted by the visuospatial sketch pad and
phonological loop functions. This suggests that when working memory functions are intact, the level of goal-setting skills is mainly related to storage processes of the phonological loop and visuospatial sketch pad functions rather than the control and regulation processes of the central executive. In children with ADHD, the central executive functions seem to be critical for the variance in goal-setting skills, and the phonological loop did not predict goal-setting skills. Children with ADHD have been shown to have deficits in the central executive (Karatekin, 2005; Mariani & Barkley, 1997; Rosenthal et al., 2006), and our results of children with ADHD may also be related to dysfunction of the central executive.

Visuospatial sketch pad functions are thought to be crucial in performing visually presented tests such as the Tower and the ROCFT (Martinussen et al., 2005; Pickering, 2001). Our finding that visuospatial sketch pad functions predicted goal-setting skills in the control group more strongly than phonological loop functions is consistent with this suggestion.

Age and Short Scale IQ did not explain the goal-setting skills in either of the groups, although the group difference in IQ was statistically significant between the ADHD and the control group. This may indicate that working memory is a more powerful predictor of goal-setting skills than IQ, at least in the IQ range of the present sample, even if the significant group differences disappeared when we used IQ as a covariate.

There are some limitations in the present study that need to be considered. The first refers to the complexity of the tests used in the study. Even tests that are designed to require the same basic element of working memory or goal-setting skills may yet tap different aspects of the functions. It has been suggested that tests like the Visuo-Spatial Test focus on visual components and the Corsi Blocks on spatial components of the visuospatial sketch pad (Della Sala et al., 1999). Similarly, the ROCFT is thought to focus on planning and organizational abilities of goal setting, whereas Tower-like tests focus on problem-solving ability. No detailed analysis of the cognitive demands of the used target tests was possible in the present sample. Therefore, the possibility of accidental variability in the results caused by the complexity of the test should be considered. Our central executive measures were verbal in nature, although recently also visuospatial central executive measures have been used (Alloway et al., 2006; Re et al., 2010). We examined children within the normal IQ range, and these children had no learning problems at school: They were rated by teachers who knew them very well. However, we did not control for very minor learning problems and their possible effect on the results.

Working memory plays a critical role in learning. Classroom performance and the development of verbal and academic skills, such as reading, decoding, reading comprehension, mathematics, and written expression, depend heavily on the adequate functioning of working memory (Dehn, 2008; Swanson, 2000; Swanson & Beringer, 1996). Common classroom activities set high demands on central executive functions, and children with ADHD are vulnerable to fail in classroom learning activities because of this demand (Alloway et al., 2006). Our results highlight the special needs of children with ADHD in classroom learning because of limited central executive resources. Our results also suggest that decreasing working memory load in classroom performance has a positive effect also on goal-setting skills of children with ADHD. In our study, children with ADHD had some deficits in visuospatial sketch pad functions. The importance of the visuospatial working memory functions especially in relation to mathematical skills has been recently indicated (Kytälä & Lehto, in press). Therefore, it is important to find out possible working memory disorders in children with problems in mathematical learning. In addition to classroom instructions, another unique way of supporting working memory functions among children with ADHD is computerized working memory training (Klingberg et al., 2002, 2005). Our results also support the suggestion that rehabilitation of working memory, especially the central executive, reduces the functional problems of children with ADHD (Klingberg et al., 2005).

In conclusion, our findings indicate that there are significant differences between children with ADHD and typically developing children in working memory and goal-setting skills as well as in which elements of working memory are critical in goal-setting situations. Goal-setting skills seem to be predicted with phonological loop and visuospatial sketch pad functions in typically developing children and with central executive functions in children with ADHD. Our results expand the understanding about the relation between different domains of working memory and goal-setting performance.

Declaration of Conflicting Interests
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References


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