Attention in preschool children with and without signs of ADHD.
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Chapter 3. Response Preparation and Response Inhibition in Preschool Children with and without Signs of ADHD

3.1 Introduction

Output related processes, or 'executive functions' play an important role in the choice, preparation and execution of optimal strategies for task performance, and inhibition of inappropriate strategies (Logan, 1985). In the present study, we tried to measure two output related functions, namely response preparation and response inhibition, in children in the age range of 4-6 years. Knowledge about attentional processes in this age range may give us an indication of later cognitive functioning such as school achievement and intelligence (Palisin, 1986), and may provide more knowledge about possible precursors of later attentional problems that might interfere with school performance (Campbell, Szumowski, Ewing, Gluck, & Breaux, 1982; Campbell, Ewing, Breaux, & Szumowski, 1986; Ruff, Lawson, Parrinello, & Weissberg, 1990).

How do attentional processes develop with age? It is well established that young children are slower information processors than older children and adults (Wickens, 1974; Chi, 1977, Kail, 1991). Wickens (1974) showed that the reaction times of younger children are significantly slower than those of older children when response preparation is less optimal. The younger child is more easily distracted and less able to focus attention initially, especially when the foreperiod of a block of stimuli is varied or lengthened. This will result in slower reaction times (Wickens, 1974). More indications for the increase of an efficient response preparation during development come from Luria (1959), who claimed that motor responses of children at the age of 3-3.5 years are very unstable, and that the nervous system becomes capable of regulating these responses more efficiently only at 5-5.5 years.

Chi and Gallagher (1982), who tried to locate the differences in speed of processing between adults and children in terms of the Sternberg (1969a, b) model, concluded that the major retardation in the children's information processing lies in the response selection stage. The authors suggested that the children seem to be hindered by task-irrelevant information. In the theory of
inefficient inhibition of Bjorklund and Harnishfeger (1990), the inefficient use of task-irrelevant information also plays an important role. These authors propose that, with development, changes in the child's neurological system lead to increased efficiency of inhibitory processing, contributing to increases in selective attention and in the ability to keep task-irrelevant information out of working memory. Following this theory, we expect that during development children will acquire more efficient inhibitory strategies.

There are clear indications that during development aspects of output related functions like response preparation and response inhibition will mature, resulting in faster information processing and fewer errors. But what happens when the attentional processes do not develop in the optimal way? According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV, American Psychiatric Association, 1994), the essential feature of children with attentional problems like Attentional Deficit Hyperactivity Disorder (ADHD) is a persistent pattern of inattention and/or hyperactivity-impulsivity that is more frequent and severe than is typically observed in individuals of a comparable level of development. Impulsivity, which can be seen as inefficient inhibition, was also found to be one of the characteristics of parent-referred hyperactive preschool children (Campbell et al., 1982, 1986). In studies with older ADHD children, Van der Meere and his colleagues (Van der Meere, Vreeling, & Sergeant, 1992) showed that the readiness to respond is delayed in ADHD children in the age range of 7-12 years, especially when interstimulus intervals are long or unpredictable. Schachar and Logan (1990a) suggested that the deficits of ADHD children lie in response-related processes. They found evidence for this claim in the finding that ADHD is associated with deficient inhibitory control (Schachar & Logan, 1990b). In another study Tannock, Schachar, Carr, Chajzyk, and Logan (1989) showed that methylphenidate (MPH) improved the efficiency of the central inhibitory mechanism in ADHD children. Because it is believed that psychostimulants, such as MPH, activate the so-called 'executive functions', this finding provides strong support for the hypothesis that ADHD children are deficient in their output-related processes.

In the underlying study we tried to manipulate the processes response preparation and response inhibition by means of a reaction time task, adapted to the age of the young children. The children had to respond to a picture of a dog, instead of the letter stimuli normally used, which, we assumed, would be less appealing to our young age groups. Correct responses to this stimulus resulted in the animation of a running dog. In the response preparation study we manipulated the timing of the responses (the stimuli appeared with variable
interstimulus times on the monitor), in the response inhibition study we manipu-
lated the response type (the child had to respond with the corresponding hand to
stimuli on the left or right side of the monitor; we varied the probability of ap-
pearance on the left or right side). As a measure of response inhibition we used
the number of errors of commission (responding with the wrong hand).

Hypotheses
Our hypotheses concerning the manipulated variables were as follows:

Reaction Times
We expected that younger children would be slower responders than older
children. Furthermore, we expected children with signs of ADHD to be slower
than control children.

Response preparation
Young children were expected to have more problems with motor preparation
than older children when timing was more difficult. The same effect was
expected when children with signs of ADHD were compared with control
children.

Response Inhibition
Because response inhibition develops with age, we expected that young children
would have more problems with this ability than older children. We also
expected that ADHD children would have more problems with inhibiting
responses than their peer controls.

A word of caution is needed here. Information processing theories have
traditionally focused on adult information processing. Cooley and Morris (1990)
stated that in the study of attention in children, adult-based paradigms have
frequently been inappropriately used. This is particularly so in studies with
children younger than 7 years. Weissberg, Ruff, and Lawson (1990) recognized
the problem as they tried to use reaction time tasks in the study of attention in
preschool children in an attempt to adapt the well-known information processing
paradigms for younger age groups. They succeeded in testing children from 2.5
to 4.5 years of age, but their results could only be interpreted after using the
observed interaction between the experimenter and the child as an independent
variable. The importance of behavioral variables in reaction time studies was
also demonstrated by Alberts (1990). In his study on facial behavior of children,
he found that ADHD children as well as control children looked away from the
monitor significantly more as the task progressed. It may be clear that, when
using adult-based paradigms to study attentional processes in young children, we have to consider behavior variables like looking away from the task. Because task orientation appears to be strongly related to age, additional information from behavioral analysis may help to correctly interpret findings from reaction time tasks. In addition to the reaction time data we videotaped the behavior of the children during this task. Our hypothesis concerning the looking away behavior of the children was as follows:

Behavioral variables
We expected that young children would show more looking away behavior during the reaction time tasks than older children. The same was expected when children with signs of ADHD were compared with their peer controls.

In this study both the normal and the deviant aspects of attention in children in the age range of 4 to 6 years were investigated. Because very little is known about these functions in this age range, it was important to find out how attention normally develops before considering attentional problems. In order to get an idea of this development, we compared children of different age groups with each other. Furthermore, we compared children with signs of ADHD with their peer controls. Because of the relatively small number of these children with signs of ADHD, no developmental analyses were done in the clinical study.

Although there may be quantitative similarities between the reactions of the ADHD children and the younger control children, we did not expect ADHD children to have a mere developmental delay. In their review of literature on developmental and clinical aspects of attention, Pearson and Lane (1990) found, beside some evidence for developmentally immature attention skills in ADHD children, factors like task characteristics and compliance which affect certain aspects of attentional processes differently in ADHD children than in their peer controls. Douglas (1980) suggested that ADHD children have a constitutional predisposition toward impaired ability to sustain attention and effort, poor inhibitory control and a tendency to seek stimulation and salience. Because of these predispositions, they will end up in a vicious cycle of increasing failure experiences, increasing impulsivity and concentration problems. One of the aims of our study is to provide more insight into the nature of attention mechanisms in young children with signs of ADHD, in an attempt to contribute to better diagnostic tools for this group.

3.2 Method
In a pilot study, we found that the reaction time tasks we used were too difficult for children younger than 4 years. Therefore, only children of 4 years and older participated in the underlying study.

3.2.1 Study 1: Response Preparation
A visual reaction time task was used as a technique to study response preparation in children in the age range from 4-6 years. Response preparation can be measured by time-uncertainty (Van der Meere et al., 1992). Our first experiment, in which response preparation was measured, consisted of two tasks, a fixed presentation rate task, and a variable presentation rate task. In the first task time-uncertainty was supposed to be minimal, and the opportunity for response preparation optimal. In the second task performance was supposed to be worse as a result of the time-uncertainty.

Subjects
Developmental Study
The subjects in the control group were from two urban schools. Parents of all children between 4 and 6 years were asked to give their permission to co-operate with this experiment. For 134 children (out of 180 children) permission was given. Table 1 gives an overview of the numbers of children per age group and gender.

Clinical study
In the clinical study we observed two groups with signs of ADHD. One group was selected from the control group, the other group was selected from children in Medical Day Care Centers (MKD). The rationale behind this is that, for various reasons, ADHD is difficult to diagnose in preschool children. With these two groups, a low-risk group and a high-risk group, we hoped to gain more insight into the specific problems of ADHD in young children. But one has to be careful, because only a few children in our groups of children with signs of ADHD were really referred with specific ADHD problems. Furthermore, the observation scales we used can be seen only as a method for preliminary screening for ADHD, not as a diagnostic tool. Children from the control-group with a sum-score above the 90th percentile of the teacher version of the Groninger Behavior Observation Scale (see Appendix A) were rated as children with signs of ADHD (Vaessen & Van der Meere, 1990). In the further analysis, these children were labelled non-referred children with signs of ADHD.
Table 1. Number of boys and girls in three different age groups (N = number of pupils, CA = mean chronological age), of the control group in the developmental study

<table>
<thead>
<tr>
<th>Age group</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>boys</td>
<td>N = 27</td>
<td>N = 28</td>
<td>N = 25</td>
</tr>
<tr>
<td></td>
<td>CA = 4.5</td>
<td>CA = 5.4</td>
<td>CA = 6.5</td>
</tr>
<tr>
<td>girls</td>
<td>N = 12</td>
<td>N = 19</td>
<td>N = 23</td>
</tr>
<tr>
<td></td>
<td>CA = 4.6</td>
<td>CA = 5.3</td>
<td>CA = 6.5</td>
</tr>
<tr>
<td>Totals</td>
<td>N = 39</td>
<td>N = 47</td>
<td>N = 48</td>
</tr>
</tbody>
</table>

The 'clinically-referred' children with signs of ADHD were recruited from four Medical Day Care Centres (MKD) in the northern part of the country. Children who visit a Medical Day Care Centre have average cognitive abilities, but have developmental problems due to physical, mental, and environmental factors. To take part in this study, children had to meet the following criteria: A sum-score above the 90th percentile on the GBO, teacher version, IQ-score of 80 or higher, no medical treatment with stimulant drugs, behavior that met DSM-IV classification for ADHD and no other disorder (see also Alessandri, 1992). Children with neurological impairments or with severe developmental disabilities (for example, mental retardation, autism) as established by medical history and child observation were excluded. A total of 26 of the 170 children from the MKD-population met the inclusion criteria and participated in our study with the informed consent of their parents. The children in both groups with signs of ADHD were matched on age and gender with children of the control group with a score below the 50th percentile on the GBO, teacher version. In the analyses we conducted several separate analyses: we compared the clinically referred children with signs of ADHD with their matched controls, the non-referred children with signs of ADHD with their matched controls, and we compared the two 'ADHD'-groups with each other. As can be seen in table 2, the latter analysis is somewhat hazardous, because the two groups of children with signs of ADHD
differ on various aspects such as the total number and the mean age of the children. Therefore the analyses concerning the comparison of these two groups were exploratory.

Apparatus
All stimuli were generated by a 80-286 Personal Computer. Stimuli were projected on a S-VGA 16-color monitor, which was situated in front of the child. A hard-plastic response tableau with one response button and two hand-shaped buttons was placed between the screen and the child (see figure 1). An Event Data Multiplexer (EDM-PC) recorded all manipulations of the three buttons on real-time basis. The times between stimulus presentation and lifting a hand, and pushing the response button, together with codes for responses with different hands were simultaneously written to a file and to a Black and White screen which was in front of the experimenter. The testing procedure was recorded by a portable VHS videorecording system. To be able to score the behaviors of the children during the RT tasks on a real-time basis, a timecode was added to the videotape afterwards.

Table 2. Number of boys and girls in the non-referred ADHD group and the clinically referred ADHD group (N = number of pupils; CA = mean chronological age; sd = standard deviation in months)

<table>
<thead>
<tr>
<th>group</th>
<th>non ref. ADHD</th>
<th>clin. ref. ADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>boys</td>
<td>N = 16</td>
<td>N = 19</td>
</tr>
<tr>
<td>girls</td>
<td>N = 3</td>
<td>N = 7</td>
</tr>
<tr>
<td>Totals</td>
<td>N = 19</td>
<td>N = 26</td>
</tr>
<tr>
<td>CA</td>
<td>CA = 5.4</td>
<td>CA = 5.0</td>
</tr>
<tr>
<td>sd</td>
<td>sd = 10.2</td>
<td>sd = 8.3</td>
</tr>
</tbody>
</table>
Procedure
Each session took place in an empty room of the school or day care centre. The child sat at a child-sized table with the response tableau and the monitor in front of it and was asked to keep both hands on the hand-shaped buttons until the picture of a small, white dog appeared on the monitor. In response to the appearance of this stimulus, the child was instructed to push the red button in the middle of the tableau as quickly as possible and then return both hands to the hand-shaped buttons. The experiment was explained to the child as a small story: A mother-dog lost all of her 24 puppies. The child was asked to bring them back home by pushing the red button at the appearance of the puppy on the monitor. The puppy appeared at the center of the monitor for a short period of time (1.5 seconds), together with a beeping sound. If the child pushed the red button within these 1.5 seconds, the little dog ran to the right side of the monitor until it was out of sight, and the image of its head appeared at the left upper corner of the screen. Simultaneously with the animation of the running dog there was the sound of a buzzer. If there was no response within 1.5 seconds, the dog disappeared from the screen. Each child had an opportunity to practice until 10 correct responses in succession were given. During the practice trials, the examiner controlled the timing of the signal and repeated the instructions if necessary. Once the procedure started, the signal was controlled automatically.
by the computer; there were two blocks of 24 trials. In the first block the delay period, the time between two consecutive stimuli\(^1\), was 4 seconds, in the second block the delay period varied between 2, 4 and 8 seconds, in random order, so that the timing of the signal was unpredictable. Each child was tested twice. The first session was considered as a practice and familiarisation situation. The second session, usually administered the next day or the same afternoon, was the real experiment.

3.2.2 Study 2: Response Inhibition

A valid method for measuring response inhibition is varying the probability of different responses (Van der Meere, Stemerdink, & Gunning, 1995; Brookhuis, Mulder, Mulder, & Gloerich, 1983), for example yes- and no-answers on different stimuli. If someone is prepared to give a yes-response because the probability of the positive stimulus is much greater than the alternative stimulus, the appearance of that alternative stimulus will force him to inhibit his yes-response. The present study consisted of two tasks. In these multi-response tasks the child had to respond with either the right or the left hand, dependent on the position of the stimulus. In the first task the probabilities for a right hand-response were equal to the probability for a left hand-response, whereas in the second task the probability for the right and the left hand was 33% and 67%, respectively. In the first task, no differences between response times with right or left hand were expected. Moreover, no differences in errors of commission between right and left hand responses were expected (an error of commission is defined as a response with the wrong hand). In the second task, faster responses and more errors of commission with the left hand were expected (because of higher probability) as compared to the right hand (we controlled for handedness, but found no differences in reaction times between right-handed or left-handed children). The number of errors of commission can be seen as an indication for response inhibition (the fewer errors of commission, the better the child is able to inhibit wrong responses).

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\(^1\)The total time between the appearance of the stimulus and the disappearance after either a good or false response was always kept constant to 2 seconds. So the delay time is in fact the time between the disappearance of a stimulus and the appearance of the next stimulus.
Subjects
In the developmental study as well as the clinical study, subjects, selecting procedure and apparatus were the same as in Study 1.

Procedure
The procedure was the same as in Study 1, except that in this study the child was told to respond with the right hand when the dog appeared on the right side of the screen, and to respond with the left hand, when the dog appeared on the left side. In the first task, the child was told that the same number of dogs (12) would appear on the right and left sides of the screen, in unpredictable order. In the second task the child was told that he could expect many more dogs on the left side of the screen (16) than on the right side of the screen (8). If the child responded with the wrong hand (an error of commission) feedback was given by a beeping sound and the appearance of a red dog on the screen.

3.2.3 Behavioral Observations
During the entire experiment, the behavior of the child was recorded on videotape. Afterwards, these tapes were scored on looking away behavior during stimulus presentation. This behavior was scored when the child was not looking at the screen (eyes or head turned away from the screen) at the moment a stimulus was presented. The procedure was that one observer scored all these behaviors of all children. His scores were compared with the scorings of a second observer. In the developmental study interrater reliability between two independent observers was measured over a random sample of thirteen children. As a measure of interrater reliability we used Cohen's Kappa (Bakeman & Gottman, 1986). We measured Cohen's Kappa over the different conditions: fixed stimulus interval (K=.51), variable stimulus interval (K=.64), response probability 50/50 (K=.59), response probability 67/33 (K=.54). The overall Kappa of the developmental study was .57. In the clinical study, we measured Cohen's Kappa for all children over the same conditions: fixed stimulus interval (K=.68), variable stimulus interval (K=.71), response probability 50/50 (K=.77), response probability 67/33 (K=.75). The overall Kappa in the clinical study was .73. According to Fleiss (1981), Kappa's of .40 to .60 can be rated as fair, Kappa's of .60 to .75 are good, and over .75 may be called excellent. According to this author, the Kappa's we measured can be rated fair to good.

3.2.4 Data Analysis
In this reaction time task, the child had to respond within 1.5 seconds. Slower responses could not reliably be measured, and were treated as responses of 1.5
seconds. Because of this all analyses were done on median reaction time, which is insensitive to variance. Since we compared two dependent variables that could be treated as repeated measures (fixed condition versus variable condition in the response preparation task, and 67%-condition versus 33%-condition in the response inhibition task), we employed a multivariate repeated measurement design (MANOVA with repeated measures). One of the assumptions of MANOVA is a normal data distribution. Reaction time data are not normally distributed, so we had to transform the data logarithmically. The independent variable was age in the developmental study and group in the clinical study. In study 1, the dependent variables were median reaction times and looking away behavior on both tasks. Task 1 (fixed interstimulus intervals) and task 2 (variable interstimulus intervals) were treated as repeated measures (within subject factors). In study 2, the dependent variables were median reaction times with left and right hands and errors of commission with either left or right hand. Task 1 (67% task) and task 2 (33% task) were treated as repeated measures (within subject factors). In the developmental study, we checked in advance for differences between boys and girls on all variables (which was not expected). Because no differences were found, gender was not treated as an independent variable. In the clinical study, differences between boys and girls were controlled by a matching procedure (that is, children in the ADHD groups were matched on age and gender with children in the control groups). Looking away behavior was analyzed in the same way as the reaction time data, and afterwards covariance analyses was carried out with looking away during stimulus presentation as a predictor of reaction time and errors of commission. Missing data resulting from equipment failure or refusal by the child meant some children had to be excluded from certain parts of the analyses. Because it was not possible to analyze the different variables in a single analysis, we corrected post hoc for chance capitalization. This means that in the developmental study we considered differences between individual age groups only if the F-values over the total groups were significant with $p < .005$. In the clinical study, where we conducted pairwise analyses, F- and t-values were considered to be statistically significant with $p < .001$.

3.2.5 Operationalizations of the Hypotheses
Because the two groups of children with signs of ADHD differed from each other (see paragraph 3.2.1), no hypotheses concerning the differences between these two groups were formulated, and only exploratory analyses were conducted.

Reaction Times
We expected that younger children would be slower responders than older children. Furthermore, we expected children with signs of ADHD to be slower than control children. The differences were measured by comparing the median reaction times of the different groups with each other.

Response preparation
Young children were expected to have more problems with motor preparation when timing was more difficult than older children. The same effect was expected when children with signs of ADHD were compared with control children. This effect was measured by comparing the median reaction times on the predictable (fixed) tasks with the median reaction times on the unpredictable (variable) tasks. The slopes of the median reaction times between the fixed tasks and the variable tasks must differ from zero (task effect). Groups must differ from each other on median reaction times (group effect), and on the slopes (interaction effect): the first two effects are required to demonstrate that the preparation task works. Only if the last effect was found, could we assume that some groups of children have more problems with response preparation in a variable situation than other groups.

Response Inhibition
Because response inhibition develops with age, we expected that young children would have more problems with this ability than older children. We also expected that children with signs of ADHD would have more problems with inhibiting responses than their peer controls. Response inhibition was measured by comparing the mean number of errors of commission with the left hand in the different groups. Requirements for demonstrating that the probability tasks worked were: no differences between left- and right-hand responses in the 50% condition; and faster responses on the 67% (left-hand responses) condition than on the 33% (right-hand responses) condition. It was expected that in the 67% condition the child would focus on responding with the left hand, and would experience problems inhibiting this response when a right-hand response had to be given. So a measure of problematic response inhibition was the number errors of commission with the left hand. If groups differed significantly from each other on the number of left-hand errors of commission, we assumed that some groups have more problems with response inhibition than other groups.
Behavioral variables
We expected that young children would show more looking away behavior during the reaction time tasks than older children. The same was expected when children with signs of ADHD were compared with their peer controls. Looking away from the task was recorded when the child clearly turned the head away from the monitor or if the eyes were clearly not directed towards the task. This behavior was scored only during the presentation of a stimulus. The number of times the child looked away, rather than duration of looking away, was scored. First, we determined whether the number of looking away behaviors differed between the groups. Second, we used this variable in covariance analysis as a predictor of reaction time, or error of commission.

3.3 Results

3.3.1 Study 1: Response Preparation
In this study we examined motor preparation. In the first section developmental data are considered, in the second the clinical data are analyzed.

Developmental Study
It was hypothesized that younger children would be slower responders, would have more problems when timing becomes unpredictable and would show more looking away behavior during the tasks. In terms of reaction times this means that not only an intercept between different age groups on reaction times should be found, but also that the slopes between reaction times on predictable (fixed) tasks and unpredictable (variable\(^2\)) tasks should differ in different age groups, the slopes in younger age groups being steeper than the ones in older age groups. Figure 2 shows the reaction times and looking away behavior of the children. Table 3 shows the analyses we conducted. The first analysis concerned the differences between the different age groups on the dependent variables. To reduce the effect of chance capitalization, we first considered the total group effect. We checked the contrasts, that is whether or not the individual groups differed from each other, only when these groups differed with \(p < .005\). The second analysis concerned the so-called task-effect: in this repeated measures analysis the variables in the fixed intervals task manipulation were compared with the variables in the variable intervals task manipulation. The third analysis

\(^2\)To minimize the chance of misinterpretation, only median reaction times on 4 second interstimulus interval trials were used in the analyses.
concerned the interaction of task and age: here we checked whether the slopes between the reaction times on fixed and variable task manipulation differed between the different age groups. In this analysis we also checked the total group-effect first before comparing the individual age groups with each other. Figure 2. Response preparation: Median reaction times and mean number of looking away behaviors during stimulus presentation of children in three age groups: 4, 5, and 6 years.

As can be seen in the figure, the younger children responded more slowly than the older ones. When we compared the groups with each other, it appeared that the 5-year-old children were not significantly slower responders than the 6-year-olds. The other groups, however, differed clearly from each other. All children had more problems with timing and motor preparation in the variable condition, than in the fixed condition. We found no age x task interaction effect. The figure also shows that 4-year-old children looked away from the monitor during stimulus presentation more often than the 5-year-old children and the 6-year-old children. The two oldest groups did not differ significantly from each other. We found no task effect on looking away behavior: the children did not look away more in the variable condition than in the fixed condition. No age x task interaction effect was found. When looking away behavior during stimulus presentation was treated as a covariate of median reaction time, age groups still differed from each other, and this effect was still mainly caused by the differ-
ence between the 4-year-old children and the two older groups. The task-effect remained significant too. We found still no significant age x task interaction.

Table 3. Response preparation and looking away behavior: multivariate analyses (MANOVA) and covariance analysis with looking away as covariate and reaction time as dependent variable, in three age groups: 4 years (N=39), 5 years (N=46), and 6 years (N=48)

<table>
<thead>
<tr>
<th></th>
<th>Main effect (age)</th>
<th>Task effect</th>
<th>Interaction (task x age)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>df</td>
<td>F</td>
<td>t</td>
</tr>
<tr>
<td>Reaction time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-5</td>
<td>2,130</td>
<td>20.22</td>
<td>***</td>
</tr>
<tr>
<td>4-6</td>
<td></td>
<td>4.58</td>
<td>***</td>
</tr>
<tr>
<td>5-6</td>
<td></td>
<td>6.20</td>
<td>***</td>
</tr>
<tr>
<td>5-6</td>
<td></td>
<td>1.64</td>
<td>***</td>
</tr>
<tr>
<td>Looking away</td>
<td></td>
<td>9.72</td>
<td>***</td>
</tr>
<tr>
<td>4-5</td>
<td>2,131</td>
<td>2.90</td>
<td>*</td>
</tr>
<tr>
<td>4-6</td>
<td></td>
<td>4.37</td>
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<tr>
<td>5-6</td>
<td></td>
<td>1.54</td>
<td>***</td>
</tr>
<tr>
<td>Covariance</td>
<td></td>
<td>12.24</td>
<td>***</td>
</tr>
<tr>
<td>4-5</td>
<td>2,129</td>
<td>3.78</td>
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<tr>
<td>4-6</td>
<td></td>
<td>4.80</td>
<td>***</td>
</tr>
<tr>
<td>5-6</td>
<td></td>
<td>1.24</td>
<td>***</td>
</tr>
</tbody>
</table>

*: p < .01
**: p < .005
***: p < .001
Clinical Study
We hypothesized that children with signs of ADHD would be slower responders, would have more problems when timing becomes unpredictable and would show more looking away behavior during the tasks than control children. In terms of reaction times this means that not only an intercept exists between reaction times of the ADHD-groups and their matched controls, but that also the slopes between reaction times on predictable (fixed) tasks and unpredictable (variable) tasks should differ from group to group, the slopes in the ADHD groups being steeper than those in the control group. In figure 3 the median reaction times and looking away behavior of all children in the four groups are shown. (In the remainder of this chapter, the control group that matched the clinically referred ADHD group is called control group 1, and the control group that matched the non-referred ADHD group is called control group 2.)

Table 4 shows the analyses we conducted. Since we conducted only pairwise analyses, only t-values are shown. To reduce the effect of chance capitalization, we considered only effects with $p < .001$ as significant. The first analysis concerned the differences between the groups on the dependent variables. The second analysis concerned the so-called task-effect: in this repeated measures analysis, the variables in the fixed intervals task manipulation were compared with the variables in the variable intervals task manipulation. The third analysis concerned the interaction of task and group: here we checked if the slopes between the reaction times on fixed and variable tasks manipulation differed between the groups. Although figure 3 suggests that all groups differed from

![Figure 3-A. Response preparation: Median reaction times and mean number of looks away during stimulus presentation for the clinically referred ADHD children and their controls](image)

![Figure 3-B. Response preparation: Median reaction times and mean number of looks away during stimulus presentation for the non-referred ADHD children and their controls](image)
each other on median reaction times, this was not so. On the whole, the children did not respond significantly more slowly in the variable condition than in the fixed condition. We also found no significant group x task interaction on median reaction time. As the figure shows, the two ADHD groups looked away during stimulus presentation more often than their matched controls, but only the difference between the clinically referred ADHD group and control group 1 could be considered significant. When looking away behavior is treated as a covariate of median reaction time, we still did not find any significant differences between any groups.

Table 4. Response preparation and looking away behavior: multivariate analyses (MANOVA) and covariance analysis with looking away as covariate and reaction time as dependent variable, in two groups with signs of ADHD (ref. ADHD, N=24; non ref. ADHD, N=19) and their matched control groups

<table>
<thead>
<tr>
<th></th>
<th>Main effect (group)</th>
<th>Task effect (task x group)</th>
</tr>
</thead>
<tbody>
<tr>
<td>df t</td>
<td>df F</td>
<td>df t</td>
</tr>
<tr>
<td>Reaction time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ref-contr</td>
<td>1,44 1.41**</td>
<td>1,44 1.26**</td>
</tr>
<tr>
<td>nref-contr</td>
<td>1,35 1.57**</td>
<td>1,35 2.06**</td>
</tr>
<tr>
<td>ref-nref</td>
<td>1,40 1.28**</td>
<td>1,40 1.06**</td>
</tr>
<tr>
<td>Looking away</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ref-contr</td>
<td>1,44 5.36***</td>
<td>1,44 13.49***</td>
</tr>
<tr>
<td>nref-contr</td>
<td>1,36 2.81**</td>
<td>1,36 3.04**</td>
</tr>
<tr>
<td>ref-nref</td>
<td>1,41 2.52**</td>
<td>1,41 13.02**</td>
</tr>
<tr>
<td>Covariance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ref-contr</td>
<td>1,43 .23**</td>
<td>1,43 .17**</td>
</tr>
<tr>
<td>nref-contr</td>
<td>1,34 .58**</td>
<td>1,34 5.91**</td>
</tr>
<tr>
<td>ref-nref</td>
<td>1,39 .17**</td>
<td>1,39 2.68**</td>
</tr>
</tbody>
</table>

*: p < .01
**: p < .005
3.3.2 Study 2: Response Inhibition

In this study we manipulated response inhibition. In the first section we analyze the developmental data, in the second section clinical data are reported.

Developmental Study

It was hypothesized that younger children would be slower responders, would have more problems with response inhibition, and would show more looking away behavior than older children. In terms of reaction times this means that we expected a significant intercept between reaction times in different age groups. Although a positive slope on reaction times between high- and low-probability-responses was expected (children show anticipation with high probability responses, therefore reaction times will be faster), the differences between age groups were expected to be found in so-called errors of commission. These types of errors are made when the child responds with the wrong hand. In other words, the child is not able to inhibit his response. In this study the probability for a left hand response was 67% and the probability for a right hand response was 33%. Before analyzing the results of this experiment, we checked in a base-line experiment whether there were differences between left hand responses and right hand responses on reaction times and errors of commission in a 50/50 situation. No differences were found.

Figure 4 shows the median reaction times in the high- and low probability situations and the errors of commission in the three age groups. Table 5 shows the analyses we conducted. The first analysis concerned the differences between the different age groups on the dependent variables. To reduce the effect of chance capitalization, we first considered the total group effect. The contrasts, that is the differences between the individual groups, were checked only if the groups differed with p < .005. The second analysis concerned the so-called task-effect: in this repeated measures analysis the variables in the 67% (left hand) condition were compared with the variables in the 33% (right hand) condition. The third analysis concerned the interaction of task and age: here we checked if the slopes between the reaction times on fixed and variable task manipulation differed among the different age groups. In this analysis we also checked the total group-effect before comparing the individual age groups with each other. All three age groups differed significantly from each other on median reaction times: younger children respond more slowly than older children. All children responded faster with the left hand (high probable response) than with the right hand (low probable response).
Figure 4. Response inhibition: Median reaction times with left hand (67%) and right hand (33%) and percentage errors of commission in three age groups: 4, 5, and 6 years.

Table 5. Response inhibition, and looking away behavior: multivariate analyses (MANOVA) and covariance analyses with looking away as covariate and reaction time, respectively errors of commission as dependent variable, in three age groups: 4 years (N=38), 5 years (N=46), and 6 years (N=48).

<table>
<thead>
<tr>
<th>Main effect (age)</th>
<th>Task effect</th>
<th>Interaction (task x age)</th>
</tr>
</thead>
<tbody>
<tr>
<td>df F t</td>
<td>df F</td>
<td>df F t</td>
</tr>
<tr>
<td>Reaction time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,129 18.31***</td>
<td>1,129 58.36***</td>
<td>2,129 .40&quot;</td>
</tr>
<tr>
<td>4-5 2.85&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-6 6.02***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-6 3.31&quot;</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(continued)
Table 5. (continued) Response inhibition, and looking away behavior: multivariate analyses (MANOVA) and covariance analyses with looking away as covariate and reaction time, respectively errors of commission as dependent variable, in three groups: 4 years (N=38), 5 years (N=46), and 6 years (N=48)

<table>
<thead>
<tr>
<th>Main effect (age)</th>
<th>Task effect (task x age)</th>
</tr>
</thead>
<tbody>
<tr>
<td>df F t</td>
<td>df F</td>
</tr>
<tr>
<td>Errors of commission</td>
<td>2,129 14.80 ***</td>
</tr>
<tr>
<td>4-5 4.28 *** 2.19 ns</td>
<td>4-6 5.16 *** 2.85 *</td>
</tr>
<tr>
<td>Looking away</td>
<td>2,131 11.43 ***</td>
</tr>
<tr>
<td>4-5 3.96 *** .80 ns</td>
<td>4-6 4.41 *** 1.40 *</td>
</tr>
<tr>
<td>Covariance (r.t. &amp; l.away)</td>
<td>2,128 12.66 ***</td>
</tr>
<tr>
<td>4-5 1.86 ns .84 *</td>
<td>4-6 4.86 *** .56 *</td>
</tr>
<tr>
<td>Covariance (err.comm. &amp; l.away)</td>
<td>2,128 7.75 **</td>
</tr>
<tr>
<td>4-5 3.06 ** 2.08 *</td>
<td>4-6 3.82 *** 2.68 *</td>
</tr>
</tbody>
</table>

*: p < .01  
**: p < .05  
***: p < .001
Because we did not hypothesize that there would be differences in looking away behaviors between the two conditions in study 2, we considered the looking away behavior only in the baseline (50%) condition.

Chapter 3: Response Preparation and Response Inhibition

As can be seen in figure 4, there was no age x task interaction. Younger children made more errors of commission than older children, but this effect was caused mainly by the differences between the 4-year-old group and the two older groups, while the two older groups did not differ significantly from each other. All children made more errors of commission in the high probability situation, and we found a significant age x task interaction on errors of commission. But this interaction was only significant between 4-year-old group and the 6-year-old group.

Table 6 shows the frequencies of looking away behaviors during stimulus presentation. As can be seen in tables 5 and 6, we found a significant age effect on looking away behavior. During stimulus presentation 4-year-olds looked away from the monitor significantly more often than 5-year-olds and the 6-year-olds, respectively. The two oldest groups did not differ from each other on looking away behavior.

Table 6. Mean number of looking away behavior during stimulus presentation, per age group

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Looking Away</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 years</td>
<td>2.72</td>
</tr>
<tr>
<td>5 years</td>
<td>.60</td>
</tr>
<tr>
<td>6 years</td>
<td>.46</td>
</tr>
</tbody>
</table>

When looking away behavior during stimulus presentation was treated as a covariate of median reaction time, the difference between the age groups on median reaction time remained significant, but this difference was caused by the differences between the two oldest groups and the 4-year-old children and the 6-year-old children. Still, all children responded more slowly with the right hand than with the left hand, and there was no age x task interaction. Co-

Because we did not hypothesize that there would be differences in looking away behaviors between the two conditions in study 2, we considered the looking away behavior only in the baseline (50%) condition.
variance analysis with looking away behavior as predictor of errors of commis-
sion showed significant differences only between the 4-year-old group and both
the 5-year-old group and the 6-year-old group. All children made more errors
of commission in the high probability situation, and we still did not find a
significant age x task effect.

Clinical Study
It was hypothesized that children with signs of ADHD would be slower
responders, would have more problems with response inhibition, and would
show more looking away behavior than control children. First, we checked if
reaction times and errors of commission with left and right hand differed in a
50% change situation. This was not the case. Next, we analyzed the data for the
experimental condition, where the probability of a left-hand response was 67%
and the probability of a right-hand response was 33%. Figure 5 shows the
results of the reaction time task.

Figure 5-A. Response inhibition:
median reaction times with left hand
(67%) and right hand (33%) and
percentage errors of commission in
the clinically referred ADHD
children and their controls

Figure 5-B. Response inhibition:
median reaction times with left hand
(67%) and right hand (33%) and
percentage errors of commission in
the non referred ADHD children
and their controls

Table 7 shows the analyses we conducted. Since we conducted only pairwise
analysis, only t-values are shown. To reduce the effect of chance capitalization,
we considered only effects with p < .001 as significant. The first analysis
concerned the differences between the groups on the dependent variables. The
second analysis concerned the so-called task-effect: in this repeated measures
analysis the variables in the 67% (left hand) condition were compared with the
variables in the 33% (right hand) condition. The third analysis concerned the interaction of task and group: here we checked if the slopes between the reaction times on fixed and variable task manipulation differed among the groups.

Table 7. Response inhibition and looking away behavior: multivariate analyses (MANOVA) and covariance analysis with looking away as covariate and reaction time, and errors of commission as dependent variables, in two groups with signs of ADHD (ref. ADHD, N=24; nonref. ADHD, N=19) and their matched control groups

<table>
<thead>
<tr>
<th></th>
<th>Main effect (group)</th>
<th>Task effect</th>
<th>Interaction (task x group)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>df</td>
<td>t</td>
<td>df</td>
</tr>
<tr>
<td>Reaction time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ref-contr</td>
<td>1.42</td>
<td>.72**</td>
<td>1.42</td>
</tr>
<tr>
<td>nref-contr</td>
<td>1.35</td>
<td>2.12**</td>
<td>1.35</td>
</tr>
<tr>
<td>ref-nref</td>
<td>1.38</td>
<td>.38**</td>
<td>1.38</td>
</tr>
<tr>
<td>Errors of commission</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ref-contr</td>
<td>1.42</td>
<td>2.91*</td>
<td>1.42</td>
</tr>
<tr>
<td>nref-contr</td>
<td>1.35</td>
<td>1.17**</td>
<td>1.35</td>
</tr>
<tr>
<td>ref-nref</td>
<td>1.38</td>
<td>1.71**</td>
<td>1.38</td>
</tr>
<tr>
<td>Looking away</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ref-contr</td>
<td>1.44</td>
<td>5.34***</td>
<td>1.44</td>
</tr>
<tr>
<td>nref-contr</td>
<td>1.36</td>
<td>2.53**</td>
<td>1.36</td>
</tr>
<tr>
<td>ref-nref</td>
<td>1.41</td>
<td>3.04**</td>
<td>1.41</td>
</tr>
<tr>
<td>Covariance (r.t. &amp; l.away)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ref-contr</td>
<td>1.41</td>
<td>2.79*</td>
<td>1.42</td>
</tr>
<tr>
<td>nref-contr</td>
<td>1.34</td>
<td>.85**</td>
<td>1.35</td>
</tr>
<tr>
<td>ref-nref</td>
<td>1.37</td>
<td>1.98**</td>
<td>1.38</td>
</tr>
<tr>
<td>Covariance (err.com. &amp; l.away)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ref-contr</td>
<td>1.41</td>
<td>.62**</td>
<td>1.42</td>
</tr>
<tr>
<td>nref-contr</td>
<td>1.34</td>
<td>.19**</td>
<td>1.35</td>
</tr>
<tr>
<td>ref-nref</td>
<td>1.37</td>
<td>.04**</td>
<td>1.38</td>
</tr>
</tbody>
</table>

*: p < .01

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Although figures 5-A and 5-B suggest differences between the groups on median reaction time, the differences were not significant. A task effect was found only in the clinically referred group and control group 1. We found no group x task interactions on median reaction times and errors of commission. Table 8 shows the looking away behaviors of the four groups. As can be seen in table 7 and table 8, the clinically referred children with signs of ADHD looked away more than their matched controls.

Table 8. Mean frequencies of looking away behavior during stimulus presentation, per group

<table>
<thead>
<tr>
<th>Group</th>
<th>Looking Away</th>
</tr>
</thead>
<tbody>
<tr>
<td>control group 1</td>
<td>.86</td>
</tr>
<tr>
<td>clin ref ADHD</td>
<td>7.64</td>
</tr>
<tr>
<td>control group 2</td>
<td>.05</td>
</tr>
<tr>
<td>non ref ADHD</td>
<td>2.90</td>
</tr>
</tbody>
</table>

When looking away during stimulus presentation was treated as a covariate of median reaction time or errors of commission, we still did not find significant results, except for effect of task on reaction time we found in earlier analyses.

3.4 Discussion and General Results

In this paragraph we will first give an overview of the most important findings of our study in the light of the different hypotheses. Next we will discuss the implications of these findings for the study of normal and deviant development of attentional process in young children and we will end with some suggestions for further research.

Study 1: Response Preparation
Developmental Data
We hypothesized that younger children would be slower responders than older children. Our findings supported this hypothesis partly: whereas the 5- and 6-year-old children did not differ significantly from one another, all the other groups did. The hypothesis that younger children would have more problems with response preparation could not be verified. The third hypothesis concerning looking away behavior was also only partly confirmed: the 4-year-old children looked away from the monitor more than the older children, but the 5- and 6-year-old groups did not differ from each other.

Clinical Data
Children with signs of ADHD did not show significantly slower reaction times than the control children, so we had to reject the hypothesis concerning the slower response times of children with signs of ADHD. We had also to reject the hypothesis that children with signs of ADHD have more problems with response preparation than control children. We did not find this in our study. Our third hypothesis stated that children with signs of ADHD show more looking away behavior than control children. This was true only for the clinically referred ADHD group when compared with the matched control group.

Study 2: Response Inhibition
Developmental Data
In this study the first hypothesis was confirmed: the younger the children were, the more slowly they responded. Our second hypothesis was that younger children would be poorer response inhibitors than older children. The data in our study supported this hypothesis partly. The youngest age group made the most errors of commission by far, in both the high and low probability situations. Furthermore, they had many more problems with response inhibition when they anticipated on the high probability response than the older children. The two older groups did not differ from each other. The third hypothesis concerned the looking away behaviors of the children. The analyses showed that the 4-year-old group again showed much more looking away behavior during the tasks than the older groups.

Clinical Data
In the clinical study the first two hypotheses had to be rejected: the children with signs of ADHD were not significantly slower than their control peers and did not make more errors of commission in either the low or the high
probability situation. Only the clinically referred ADHD children showed more looking away behaviors during the tasks than their control group.
General Conclusions
This study of attention in preschool children shows that it is possible to use reaction time tasks in this young age group. But one has to be careful. The reaction time data as such are relatively poor indicators of age differences in task orientation; most of the time we need to supply behavioral analysis to reach our conclusions. The overall conclusions are that age differences were found on overall task orientation and response inhibition, but not on response preparation. Most differences lie between the ages of 4 and 5, indicating that there may be a shift in attentional development in this period.

Our clinical study shows that task orientation is the only discriminator between clinically referred children with signs of ADHD and their control group in a reaction time task. The lower task orientation is the main factor explaining slower reaction times and more errors of these clinically referred group in reaction time studies. The finding that this group differed from their control group on task orientation, a variable which was not found to be the main discriminator in the developmental study, shows that ADHD is not merely a developmental delay. We tend to agree with Douglas (1980) that the problematic task orientation is not a good predictor for optimal development. But before drawing such a conclusion, more children with signs of ADHD of different young age groups will have to be compared in a developmental study.

What is the consequence of not finding differences between the children with signs of ADHD and the control children in any manipulation? Does this mean that the Reaction time tasks are not appropriate for preschool ADHD children? The answer to this question is more complicated than a simple 'yes' or 'no'. Why didn't we find differences between control children and children with signs of ADHD on the tasks? An important reason for not finding differences in the response preparation task may be caused by the following: we tried to manipulate response preparation by varying the interstimulus intervals within the blocks of trials. There are strong indicators that varying the interstimulus intervals between blocks of trials affects response preparation more than the method that we chose (Wickens, 1974; Van der Meere, Vreeling, & Sergeant, 1992). But for practical reasons, we were not able to perform this manipulation. We strongly suggest that future research should try to manipulate response inhibition with varying interstimulus intervals (and thus preparation times) between blocks of trials (for example blocks of 24 trials with interstimulus intervals of 2 seconds, blocks with intervals of 4 seconds, etcetera) before deciding on whether or not the task is able to identify response preparation problems in preschool ADHD children. But, and this is especially the case...
with ADHD children, the researcher should capitalize on this manipulation only rather than manipulating other aspects as well in a single session, because we observed that the reaction time tasks were very demanding for preschool ADHD children. In our opinion the fact that no significant differences were found in the response inhibition task has two main causes: the small number of children in this study and the small number of trials in the high- (16) and low- (8) probable condition. In order to draw hard conclusions from this study, either the number of children, or the number of trials, or both should be increased. The first possibility - increasing the number of children in the study - is highly dependent on the number of available preschool ADHD children one is able to select, which may be problematic. To increase the number of trials in this study is of course possible. This can only be done when the researcher decides to focus only on the manipulation of response inhibition, because otherwise the results will be strongly influenced by unwanted effects from factors like boredom, fatigue, etcetera.

Further Directions and Implications
In line with the few known studies on attention in preschool children (Ruff & Lawson, 1990; Harper & Ottinger, 1992), we showed that it is possible to administer reaction time tasks to preschool children. We were able to show developmental differences in motor related abilities, namely response inhibition. The findings in the clinical study show that the differences between ADHD preschoolers and their peers lay mainly in task orientation: particularly when timing becomes unpredictable, preschool children with signs of ADHD tended to look away more often than their peer controls. Besides the suggestions made in the former paragraph, it is likely that a vigilance-like task like the one developed by Harper and Ottinger (1992), where timing is unpredictable and waiting times are long (10 to 60 seconds between two stimuli), in addition to detailed behavioral observations, can give a better insight in the attentional processes of preschool ADHD children. An alternative is the observation of task orientation of these children in a free play situation, where the quality of task orientation and off-task behavior can be exhaustively analyzed.

One important rationale behind the present study was to investigate possibilities for the early diagnosis of attentional problems like ADHD. The results of our study make clear that we are able to detect factors like task orientation which are responsible for attentional problems in young children with signs of ADHD. Furthermore, ADHD appears not to be simply a developmental delay. These findings give support to the suggestions of authors like
Douglas (1980), and Pearson and Lane (1990). In the view of Douglas (1980) the ADHD child will end up in a vicious cycle of increasing failure experiences, increasing impulsivity and concentration problems. In order to prevent ADHD children from entering this cycle, it is very important to detect the signals of ADHD before school age. Our study shows that such detection is possible. More research has to be carried out, especially in the field of developmental aspects of ADHD problems, but in the near future we may be able to develop an instrument for the early diagnosis of ADHD problems, and help the ADHD child to avoid the path towards serious conduct disorders, which may eventually lead to antisocial or even criminal behavior.

Acknowledgements
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References


