Universiteit Utrecht

Sustained attention in children

Comparing children with chronic diseases or conditions with their healthy peers

Abstract

Sustained attention is an often studied cognitive domain. It is one of the basic cognition functions in humans and necessary for many skills in the development of a child. In the past, research in sustained attention has been done with healthy children and children with a specific chronic disease. In this study, children with all kinds of chronic diseases or conditions are compared with healthy children using a digitalised version of the Bourdon-Vos test. Based on this test, it has been found that children with a chronic disease or condition perform less on the test and have a decline in detection rate over time compared to healthy peers. However, no differences in speed have been found between the two groups.

Utrecht, August 20, 2016

Name: J.H Meessen

Email: J.H.Meessen@students.uu.nl

Student number: 3823865

Supervisors

Name: T.C.W. Nijboer

Contact details: T.C.W.Nijboer@uu.nl

Name: M. Zwinkels

Contact details: M.Zwinkels@dehoogstraat.nl

Table of contents

Sustained attention in children

Comparing children with chronic diseases or conditions with their healthy peers

Keywords: Sustained attention, Bourdon-Vos, digitalization, chronic disease or condition.

Introduction

Attention is one of the basic cognition functions in humans. It is commonly defined as the identification and selection of particular sensory input for more detailed processing (Leman, Bremner, Parke & Gauvain, 2012) and a crucial skill in normal development and functioning. An important part of the attention spectrum is sustained attention. Sustained attention is an individual's ability to maintain focus on a specific stimulus or a specific task (Graziano, Calkins & Keane, 2011; Ashcraft & Radvansky, 2010). Posner and Petersen (1990) developed a framework of attention. They stated that three attention systems are distinguishable: an orienting system, an executive attention system and third, an alertness system. In the current study, the focus will lie on the alertness system. The alertness system, also called vigilance system, enables a person to point their attention and maintain it for a longer period. When the alertness is maintained for a longer period, it is called sustained attention (Kessels, Eling, Ponds, Spikman & van Zandvoort, 2012). Sustained attention can be affected by many processes in the development of children. Neural and neurotransmitter systems affect the ability of children to sustain their attention (Oken et al, 2006). Furthermore, the frontal cortex develops during childhood (Casey, Tottenham, Liston & Durston, 2005) and is, according to Fan et al (2005), important in sustained attention. When children are young, they have difficulty controlling their sustained attention. As they develop and their brain develops, this control increases (Leman et al., 2012). As said, sustained attention starts with alertness. Therefore, children need to be motivated to stay alert and sustain their attention (Oken, Salinsky and Elsas, 2006).

There are several reasons why sustained attention and research in sustained attention are important. The ability of a child to sustain attentional control over time is an important indicator of functioning in activities in daily living (Swaab-Barneveld et al., 2000) as well as school performance (Kessels, Eling, Ponds, Spikman & van Zandvoort, 2012; Steinmayr, Ziegler & Träuble, 2009), social behaviour (Kessels et al., 2012; Pérez-Edgar et al., 2010) and emotion regulation (Walcott & Landau, 2004). McGoey, Eckert, DuPaul (2002) showed that earlier detection of sustained attention deficits have a positive effect on treatment outcomes because of earlier interventions. Deficits in sustained

attention develop rapidly into more widespread cognitive problems (Sarter et al., 2001). So it is important to develop tests that trace these problems in an early stage.

In the past, research has been done to investigate sustained attention in children and adolescents who are developing typically and those with a specific chronic disease (Bottcher, Meulengracht Flachs & Uldall, 2010). However, little research has been done on children and adolescents with a chronic disease or physical disability as one group. Because these children tend to have a different developmental course compared to typical developing children and often end up in special education (Hallahan, Kauffman & Pullen, 2012), it is important to investigate every aspect of their development, which thus includes the quality of sustained attention. When norms are set for sustained attention in children with a chronic disease or physical disability, interventions can be started to diminish attentional problems and problems caused by the attentional deficits in this group in the future. The aim of the study is to test whether there are differences in sustained attention between children with a typical development and children with a chronic disease or condition. The findings will contribute to more accurate measures for both groups.

Several tests, such as Bourdon-Vos and D2, have been developed to measure sustained attention. For this research, the Bourdon-Vos test has been used because it is a simple task and appropriate for children in a wide range of ages (Bul & van Baar, 2011). The original Bourdon-Vos is a paper and pencil task in which children have to cancel specific stimuli over a longer period of time (Swaab-Barneveld et al., 2000). In the paper and pencil task, it was possible to measure a decline in accuracy over time. However, it was impossible to measure the exact moment when this decline starts and the course of this decline. For this research, a digital version has been developed in which the exact course of attention can be measured and subtle malfunctions in sustained attention will be recognised in an earlier stage. Moreover, a digital task requires less motor skills which can be problem in this population.

It was expected that children and adolescents with a chronic disease or condition would score significantly lower on the Bourdon-Vos test compared to their typical developing peers. It was expected that these children would have less hits and an earlier decline in hits would appear compared to their healthy peers. Second, it was expected that these children would perform the test slower than their healthy peers and that there would be an earlier moment on which the increase in time started.

Methods

Children:

In total, 301 children participated in this research, of which 132 were children with a chronic disease (CD group) and 179 were their healthy peers (HC group). For the CD group, data of two studies were used; the Sport-2-Stay-Fit study (Zwinkels et al 2015) and the Health in Adapted Youth Sports (HAYS) (Lankhorst et al 2015) Children were included in the CD group if they were aged from 6 up to 19 years with a physical chronic disease or condition, including cardiovascular, pulmonary, musculoskeletal, metabolic or neuromuscular disorders. Both children and adolescents who are ambulatory or propelling a manual wheelchair were included. Children were included in de HC group if they were 6 to 19 years old and did not have a physical chronic disease or condition.

Before the test procedure started, both parents had to sign an informed consent form. If the child was twelve years or older, he/she had to sign an informed consent as well.

The Medical Ethics Committee of the University Medical Center Utrecht approved all study procedures (NTR4698) and judged that HAYS was not bound to the liabilities under the WMO-act, however Sport2StayFit was. Furthermore, both studies comply with the declaration of Helsinki.

Procedure:

In the part of the study in which the child performed the Bourdon-Vos test, the child sat down with the tablet on the table in front of him/her. The test took place in a quiet room, accompanied by one examiner. The instructions were given verbally. The child was told that there would be three kinds of groups on the screen with either three, four or five dots and he/she had to press the groups with four dots as quick and accurate as possible. The child had to perform the test as if he was reading a book, left to right, line after line. It was not allowed to return to an earlier group when he/she saw a missed group of four dots (corrections). There were 35 lines, if the child had not finished all lines in ten minutes, the test was stopped.

Task, Stimuli, and Outcome Measures:

The current study was part of a larger study focusing on health effects of sport participation in children and adolescents with a chronic disease or condition (Lankhorst et al., 2015; Zwinkels et al., 2015). In the case report form of the children, general information such as age, gender and health problems of the child were noted. In addition to this case report form, every child filled out a questionnaire about their physical condition and sport behavior.

One of the tests in the cognitive test battery of the larger study was the Bourdon-Vos. A digital version of the Bourdon-Vos test is used on an Asus Eee slate tablet with touch screen capabilities (12.1 inch display with the resolution of 1366x768 pixels and clock speed of 1.33 GHz).

The test contained three pages with a total of 35 lines, each line containing 24 groups of either three, four or five dots. The child had to select every group of four dots from the left to the right, line after line. Every line consisted of eight groups with four dots. In total there were 280 targets and 560 distractors. The selection of groups of dots was either seen as a hit (correct selection of a target), miss (false rejection of a target), false alarm (selection of a distractor), or a correct rejection (correct rejection of a distractor). The outcome measures were (1) amount of hits per line (2) the amount of time spent on a line (measured between first and final hit). And (3) total hits and time spent on the test.

Analyses:

Figure 1 shows which steps were performed to exclude children and to prepare the data for analysis. Some children performed accidental hits, for example by pressing with the elbow on the tablet. Furthermore, to be able to draw reliable conclusions from the experiment, we cut off the score based on how far 80% of the children had come. 80% of the children in the CD group reached line 26 as final line. In the control group, 80% reached line 30 as final line. Because the CD group completed the task to a smaller extend, 26 lines is chosen as cut-off line for data analysis.

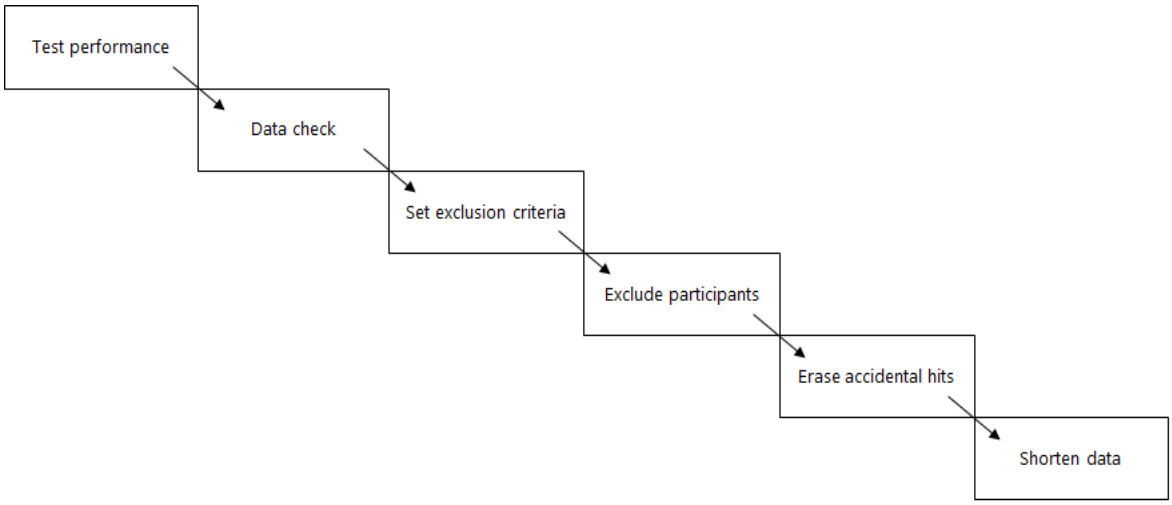


Figure 1. Data preparations before analysis

To analyse the data, the test output first had to be converted into data that was suitable for SPSS analysis by the use of Matlab. The delivered, rough data consisted of coordinates with corresponding time points. This output was converted to data that represented whether it was a good or false response and in what speed the responses were given. This data showed that many children had made rule violations. Therefore, exclusion of children who had made too many rule violations had to take place. The rule violations can be found in table 1.

Table 1.

Rule violations per group

Amount of violations	**CD**	**HC**
Lines skipped		
0	88,14%	97,04%
1	7,63%	1,18%
2	1,69%	1,18%
3	1,69%	0,59%
4	0,85%	0,00%
5	0,00%	0,00%
>5	0,00%	0,00%
Lines backward		
0	92,37%	96,45%
1	5,93%	2,37%
2	0,00%	0,59%
3	0,85%	0,59%
4	0,00%	0,00%
5	0,85%	0,00%
>5	0,00%	0,00%
Corrections		
0	44,92%	38,46%
1	27,12%	22,49%
2	7,63%	16,57%
3	4,24%	10,06%
4	5,08%	2,37%
5	6,78%	1,18%
>5	4,24%	8,88%

Based on rule violations the children made the following criteria were set:

- children who skipped more than one line are excluded
- children who checked lines backwards are excluded
- children who made more than three corrections are excluded

The main question of this research was whether there is a difference in performance on the task between children with a chronic disease or condition and normal developing children. This question was answered by performing the following analyses.

To compare the groups on total hit rate, an independent samples T-test was performed. To compare the mean hits rate between the groups, a repeated measures ANOVA between groups with post-hoc analysis within groups was done. This was performed on the hits on line 1, 13 and 25. The choice for three lines was made to have enough power for reliable results. These lines were chosen because they are the first line of each page. To compare the groups on total time, again an

independent samples T-test was performed. To compare the groups on the moment when the decline in tempo started, a repeated measures ANOVA between groups with post-hoc analyses within groups was done. Time was measured between the first and last target of the line. The comparison was made between line 4, 13 and 26 to have enough power for reliable results. These lines were chosen because these lines had the same amount of targets and distractors between the first and last target.

To be able to have reliable results from the repeated measures ANOVA, several assumptions had to be met. All assumptions were met except Mauchly's test of sphericity, $p<0.05$. Therefore, a Greenhouse-Geisser correction is used. Also the equal variances were not found for each outcome measure. Because of these violations, another analysis may be more suitable to answer the question. However, SPSS does not offer another analysis. Therefore, the repeated measures ANOVA is used to analyze the data.

A Mann-Whitney U test showed a significant difference in age between the groups ($p<0.001$). The CD group was significantly older than the HC group. Because this difference could influence the data analysis, the variable age was added as covariate in further analysis.

Results

In the CD group, 44 children had to be excluded because of too many rule violations (see table 1). 88 children in the CD group were included of which 53 were boys and 35 girls. In the HC group, 31 children had to be excluded for the same reasons. 148 children were included in the HC group of which 59 were boys and 89 girls. Detailed information about the participants is given in table 2.

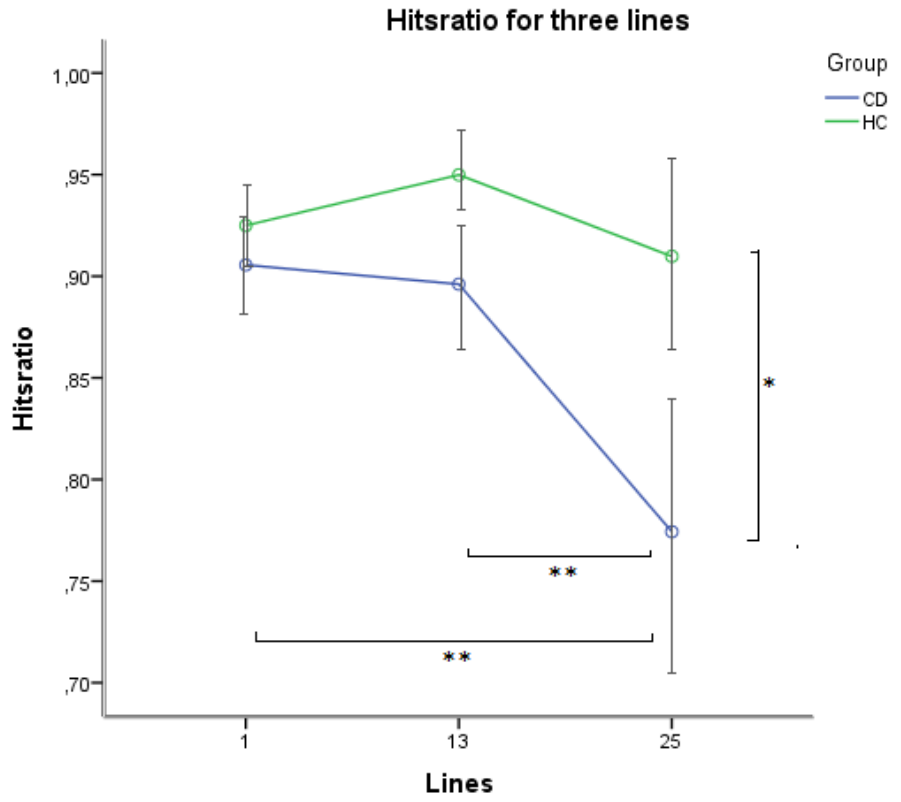
Table 2.

Descriptive statistics

	CD n=88	**HC n=148**
Age (y)		
Mean (±SD)	14,3 (±2,8)	10,3 (±2,4)
Range	9-19	6-18
Boys	60%	40%
Girls	40%	60%
Condition		
Cardiovascular	8,0%	NA (not applicable)
Pulmonary	3,4%	NA
Musculoskeletal	16,1%	NA
Metabolic	11,5%	NA
Neuromuscular	60,9%	NA

The Levene's test performed in the t-test on total hits was significant (p<0.001), therefore equal variances were not assumed. With respect to total amount of hits, children with CD (M=21.5, SE=0.55) showed a lower performance compared to HC children (M=23.7, SE=0.18) (t(105.33)=-3.77, p< 0.01; see Figure 2).

A significant difference between both groups was observed with respect to hits on three lines (line 1, 13 and 25), F(1.356, 288.112)=4.448, p=0.024 (Figure 2), with a higher hits ratio for the HC children compared to the CD children. However, the effect size is small, η^2=0.0021. After the repeated measures ANOVA, a Bonferroni post-hoc analysis was done to see whether the amount of hits on these three lines differed significantly within the groups. This showed that there is a significant difference p=0.040 between line 1 and 25 and between line 13 and 25 for the CD group (in Figure 2). In the HC group, no significant differences between lines were found.



Covariates appearing in the model are evaluated at the following values: Age = 11,79

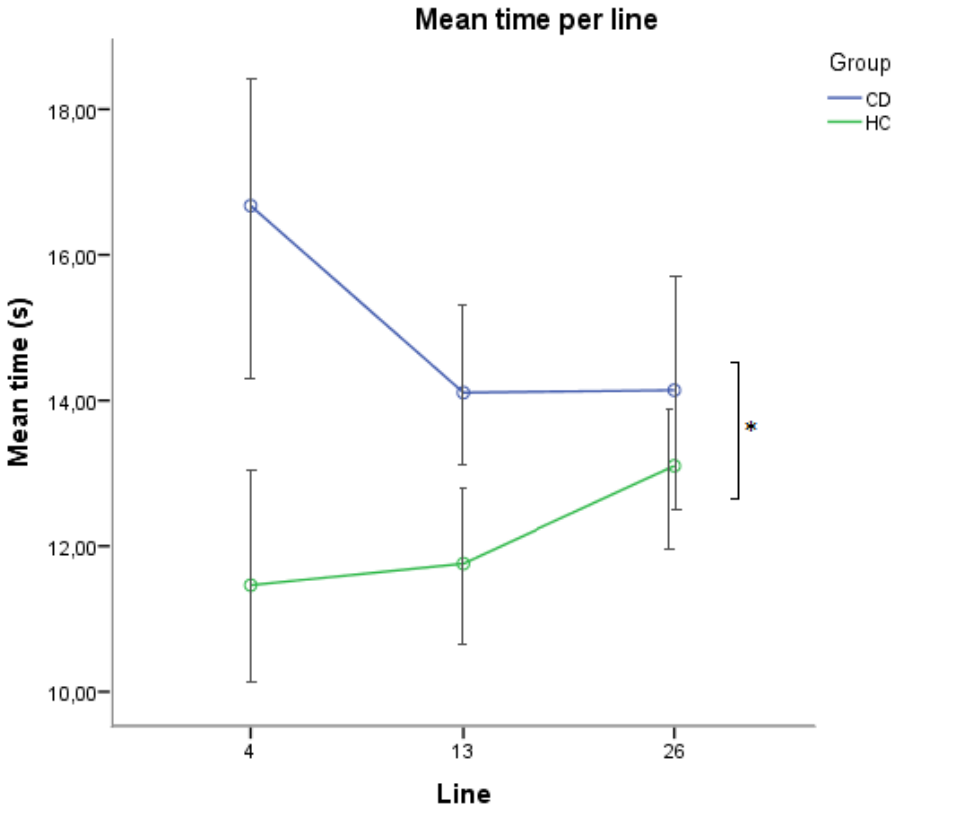
* significance between groups ; ** significance within groups

Figure 2. Mean hits ratio for line 1, 13 and 25 for both groups.

Time has also been compared between the groups. For the comparison of total time, the Levene's test for equal variances was not significant, p=0.114. Therefore, it can be assumed that the variances were equal. With respect to total time, children with CD (M=313.8, SE=10.8) did not spend more time on the test compared to HC children (M=310.3, SE=7.2). The small difference was not significant $t(232)$=-4.5, p=0.783.

The repeated measures ANOVA was also done on time for three lines: 4, 13 and 26 because these lines contain the same amount of targets and distractors between the first and last target. For this analysis, the assumption of sphericity was significant p=0.000. Therefore, the Greenhouse Geisser correction was used. Levene's test for equal variance was significant for line 4, but not for line 13 and 26. The ANOVA showed that there is a significant difference between the groups on these three lines $F(1.582, 324.264)$=5.257, p=0.01 as can also be seen in figure 3. The HC group works faster than the CD group. The average time on line 4 was 14.50 seconds for the CD children and 12.59 seconds for the HC children. On line 13, CD children spent 12.54 seconds and HC children 12.57 seconds. On line 26 CD children spent 13.31 seconds and HC children spent 13.53 seconds. The effect size is small, η^2=0.025.

Also for time, a Bonferroni post-hoc analysis was done to see whether the time on these three lines differed significantly within the groups. There are no significant difference in time between these three lines for both groups.



Covariates appearing in the model are evaluated at the following values: Age = 11,85
* significance between groups ; ** significance within groups

Figure 3. Mean time in seconds for lines 4, 13 and 26.

Discussion and conclusion

The aim of this study was to investigate whether children with a chronic disease or condition perform different on a task used to measure sustained attention than their healthy peers.

The results show that there is a significant difference between the groups with respect to age and gender. The CD group is significantly older than the HC group. The CD group had less hits in the total experiment than the HC group, this is also the fact when the groups are compared on hit ratio on three lines. Within the CD group, the children made less hits in the end of the experiment than in the beginning. Within the HC group, there is no such decline in hits.

With respect to total time spent on the experiment, there is no difference between the two groups. However, if the groups are compared on the three lines, CD children take more time to check the same lines as the HC children do. Within the groups, there is no significant difference between speed in the beginning and end of the experiment. Summarizing, the CD group has a decrease in hits but no significant difference in time. The HC group has neither a decrease in hits nor a difference in time. When the groups are compared, the children in the CD group have less hits but need the same amount of time as the HC children on the total experiment.

Sarter and colleagues (2001) report that in tasks used to measure sustained attention, an increase in reaction time and a decrease in hits is usually found. In this study, only the decrease in hits has been found and only for the CD group. The children in the HC group are able to sustain their attention for the time the test takes. This can be explained by the fact that this experiment was relatively short to measure sustained attention, when a longer test would have been used (e.g. a test that takes one hour), a decline in attention in the HC group may be found (Raz & Buhle, 2006). Bul and van Baar (2012) performed a study on children in special education and children in regular primary schools. They measured time per line on the paper and pencil Bourdon Vos and found that children in special education need more time than the children in general primary schools to complete a line. This finding is the same as the findings on time in the current study.

An explanation for the differences between both groups is that adolescents with chronic diseases or conditions have a higher risk to have comorbid ADHD than their healthy peers (Nylander, Fernell & Tindberg, 2015), this is probably also the case in children. The DSM-5 states that one of the core problems in children with ADHD is a malfunctioning sustained attention (American Psychiatric Association, 2013). Children with ADHD have difficulties to keep their attention on one task for a prolonged time. This higher risk of comorbidity with ADHD explains the lower performance of CD children on the task done in this study than their healthy peers.

Concluding, the results show that the first hypothesis can be partially confirmed. CD children have less hits than their healthy peers. However, both groups only have a within group difference

between the first and last line. This means the decline does not start earlier in the CD group. The second hypothesis has to be rejected, there is no significant difference between the groups on total time and within the groups there is no significant decline or increase of time over the different lines of the experiment.

The violations of the assumptions for the ANOVA analyses may have some consequences that have to be taken in account. The violation of sphericity causes a too liberal testing when a repeated measures ANOVA is used. This leads to an increasing risk of type I errors (Field, 2009). The violation of homogeneity increases this risk as well (Field, 2009).

A limitation of the experiment was the length of the experiment. The experiment took at most ten minutes. In most cases, the children finished it earlier than these ten minutes. This is rather short to measure sustained attention. In some studies, sustained attention is measured for several hours (Raz & Buhle, 2006). On the other hand, this study was done with children, it may not be ethical to test their sustained attention for several hours. Second, the test was taken by many different examiners, many of them without any knowledge of the test. It is possible that there have been small differences in instructions between these examiners and this may have contributed to the relative high amount of rule violations. Research done to investigate the interrater reliability of the paper and pencil version of the Bourdon Vos showed an interrater reliability of 97% (Kaldenbach, 2015) and in another study of .84 (Bul & van Baar, 2012). However, in the paper and pencil study, all the examiners were psychologists with knowledge of the test. Third, there was a big difference in test battery between children in de CD group and HC group. The first group had to perform a test battery that took about 3 hours, in which they had to perform physical tests and three cognitive tests. In the Sport 2 Stay Fit study, the cognitive test battery was taken in the beginning of the whole test battery. However, in the HAYS study, the cognitive test battery was taken after one hour of testing. The children in the HC group only had to perform the three cognitive tests. It is possible that these differences may have influenced the results because motivation fluctuates during the course of a test battery and motivation is a major component of sustained attention (Oken et al, 2006). Another shortcoming is the difference in sample-size. This large difference had a negative influence on the equal variances. In further research, equal group-sizes are necessary. At last, the choice for a repeated measures ANOVA between the groups with a covariate was a problem for this study because of the violations of assumptions. In future research another statistical program with different statistical analyses should be used to diminish the type I error rate.

For future research, it may be interesting to either have a more heterogeneous CD group. The CD group was heterogeneous, but the amount of different diagnoses was relatively small. Because of relatively little difference between the main diagnoses of these children, it is not possible

to draw conclusions for CD children in general. To be able to draw the best conclusions for this group as a whole, a bigger sample is required with more different diagnoses included in the sample.

In this study, small differences in sustained attention have been found between children with a chronic disease or condition and their healthy peers, especially in accuracy. The difference can be explained by the higher chances on ADHD, and thus problems in sustained attention, in children with chronic diseases or conditions. Further research is necessary to compare these groups more carefully to be able to give every child the same chance for a well-functioning sustained attention and all the benefits this brings.

References

Ashcraft, M.H. & Radvansky, G.A., (2010). *Cognition, fifth edition*. New Jersey: Pearson Education, Inc.

Bottcher, L., Meulengracht Flachs, E. & Uldall, P., (2010). Attentional and executive impairments in children with spastic cerebral palsy. *Developmental Medicine & Child Neurology, 52.* p. 42-47.

Bul, K.C.M. & van Baar, A.L. (2011). Behavior Problems in Relation to Sustained Selective Attention Skills of Moderately Preterm Children. *Journal of developmental and physical disabilities, 24.* p. 111-123.

Casey, B.J., Tottenham, N., Liston, C., & Durston, S. (2005). Imaging the developing brain: what have we learned about cognitive development? *Trends in cognitive sciences 9(3).* p. 104-110.

American Psychiatric Association, (2013). *Diagnostic and statistical manual of mental disorders (5th edition).* Washington, DC.

Fan, J., McCandliss, B.D., Fossella, J., Flombaum, J.I., & Posner, M.I. (2005). The activation of attentional networks. *Neuroimage, 26,* p 471-479.

Field, A., (2009). *Discovering statistics using SPSS.* London: SAGE publications.

Graziano, P.A., Calkins, S.D. & Keane, S.P., (2011). Sustained Attention Development during the Toddlerhood to Preschool Period: Associations with Toddlers' Emotion Regulation Strategies and Maternal Behaviour. *Infant and Child Development, 20.* p. 389-408.

Hallahan, D.P., Kauffman, J.M. & Pullen, P.C., (2012). *Exceptional learners: An Introduction to Special Education, twelfth edition.* Essex: Pearson Education.

Kaldenbach, Y., (2015). Het meten van volgehouden selectieve aandacht bij kinderen en jongeren. Welke rol speelt de onderzoeker bij de uitkomsten van de Bourdon-Vos test? *GZ-psychologie, 7(7).* p. 8-12.

Kessels, R., Eling, P., Ponds, R., Spikman, J. & van Zandvoort, M., (2012). *Klinische Neuropsychologie.* Amsterdam: Uitgeverij Boom.

Lankhorst, K., van der Ende-Kastelijn, K., de Groot, J., Zwinkels, M., Verschuren, O., Backx, F., Visser-Meily, A., Takken, T., (2015). Health in Adapted Youth Sports Study (HAYS): health effects of sports participation in children and adolescents with a chronic disease or physical disability. *Springerplus, 4.* p. 796.

Leman, P., Bremner, A., Parke, R.D. & Gauvain, M., (2012). *Developmental Psychology.* London: McGraw-Hill Higher education.

McGoey, K.E., Eckert, T.L. & DuPaul, G.J., (2002). Early Intervention for Preschool-Age Children with ADHD: A Literature Review. *Journal of Emotional and Behavioral Disorders, 10(1).*

p. 14-28.

Nylander, C., Fernell, E. & Tindberg, Y., (2015). Chronic conditions and coexisting ADHD- a complicated combination in adolescent.

Oken, B.S., Salinsky, M.C., & Elsas, S.M. (2006). Vigilance, alertness or sustained attention: physiological basis and measurement. *Clinical neurophysiology, 117 (9),* p 1885-1901.

Pérez-Edgar, K., Martin McDermott, J.N., Korelitz, K., Degnan, K., Curby, T.W., Pine, D.S. & Fox, N.A., (2010). Patterns of Sustained Attention in Infancy Shape the Developmental Trajectory of Social Behavior From Toddlerhood Through Adolescence. *Developmental Psychology, vol. 46, no. 6.* p. 1723-1730.

Posner, M.I., & Petersen, S.E., (1990). The attention system of the human brain. *Annual review of neuroscience, 13.* p 25-42.

Raz, A., & Buhle, J. (2006). Typologies of attentional networks. *Nature reviews neuroscience, 7.* p. 367-379

Sarter, M., Givens, B. & Bruno, J.P. (2001). The cognitive neuroscience of sustained attention: where top-down meets bottom-up. *Brain research reviews, 35(2).* p. 146-160.

Steinmayr, R., Ziegler, M. & Träuble, B., (2009). Do intelligence and sustained attention interact in predicting academic achievement? *Learning and Individual Differences, 20.* p. 14-18.

Swaab-Barneveld, H., de Sonneville, L., Cohen-Kettenis, P., Gielen, A., Buitelaar, J. & van Engeland, H., (2000). Visual Sustained Attention in a Child Psychiatric Population. *Journal of the American Academy of Child & Adolescent Psychiatry, 39(5).* p. 651-659.

Walcott, C.M. & Landau, S., (2010). The Relation Between Disinhibition and Emotion Regulation in Boys With Attention Deficit Hyperactivity Disorder. *Journal of Clinical Child & Adolescent Psychology, 33 (4).* p. 772-782.

Zwinkels, M., Verschuren, O., Lankhorst, K., van der Ende-Kastelijn, K., de Groot, J., Backx, F., Visser-Meily, A., Takken, T., (2015). Sport-2-Stay-Fit study: Health effects of after- school sport participation in children and adolescents with a chronic disease or physical disability. *BMG Sports Science, Medicine and Rehabilitation, 7.* p. 22.