The impact of Wii-fit intervention on children with ADHD

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Abstract

In this pilot-study it has been studied if Wii-fit games have an impact on attention in children with ADHD. Currently, medicine based treatments are considered first line treatments in Western countries for treating ADHD. Side-effects and other complications with medication often lead to discontinuation. Additional treatment options, like exergames may be an alternative to cover these issues. In this study it has been studied if a Wii-fit gaming intervention would have an effect on attentional abilities in children with ADHD. According to literature physical activity and medication can improve attention and ADHD symptoms in children with ADHD. This has also been studied during this intervention by dividing children in categories of Medication/NoMedication and PAHigh/PALow. The results showed a small improvement in attention, with a significant effect in selective attention. The number of hours of physical activity are not related to the learning abilities of the children. Medication did have an effect on the Wii-fit game scores, where children who used medication performed better in games containing sustained than the children who were not on medication. Within all the groups of exercise and medication the children showed a significant improvement from the first to the last session in most Wii-Fit games. More research needs to be done to confirm these results and follow-up studies should include control-groups to compare clinical groups with non-clinical groups. Furthermore, these results show promising features for follow-up studies focused on ADHD interventions, where exergame interventions may be offered as additional intervention to improve attentional abilities.

Keywords: Wii-Fit games intervention, children with ADHD, pre-posttest, feasibility

The impact of Wii-fit intervention on children with ADHD

Attention deficit hyperactivity disorder (ADHD) is an highly prevalent behavioral disorder among children. It affects 5% of the children worldwide (Sayal et al., 2018). The symptoms of ADHD include a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development (5th ed.; DSM–5; American Psychiatric Association, 2013). Some core deficits linked to ADHD are sustained attention and selective attention that is necessary to perform a given task. Besides attentional problems, children with ADHD also show faults in executive functioning (Gupta & Kar, 2010). Children who suffer from these symptoms exhibit great deviations from their developmental level, great enough to create functional impairment in major life activities, such as home, school and peer relationships (Sasser et al., 2017). In the classroom for example, children with ADHD tend to finish less work, tend to underachieve, violate classroom rules more often, and may ultimately fail to graduate (Dupaul, 2007). Within peer relationships, children with ADHD tend to be more bossy, immature, and aggressive than their peers (Hoza, 2007). At home, families of children with ADHD are characterized by increased family conflict, negative parenting practices, and parenting stress (Johston & Mash, 2001). There is also an higher risk for children diagnosed with ADHD to develop signs of substance abuse, comorbidity with other mental disorders, self-harm and criminal behaviour, as well as reduced life expectancy (Young et al., 2016; Dalsgaard et al., 2015; Dalsgaard et al., 2014).

ADHD occurs due to neurobiological alterations. A dysfunction in dopaminergic transmission in structures such as the striatum and the frontal lobe can be seen as the main source (Vaidya et al., 1998).These alterations impair attention but also executive functions including motor control, working memory and inhibitory control. According to the dopamine transfer deficit theory (DTD) some of the symptoms of ADHD can be explained by a failure of the dopamine cell response to transfer to earlier predictors of reward (Tripp & Wickens, 2008). Dopamine is an important transmitter in the reward-system, specifically in people with ADHD: It is believed that the dopamine cell response to the cue that predicts reinforcement, is reduced to the point of being ineffective. The cell response only occurs after the positive

reinforcer is delivered. One of the brain-regions involved in the DTD theory is the prefrontal cortex, which contains D4 receptors. D4 and D5- receptors are dopamine receptors and differ in people with ADHD. In the rewards-system it is thought that the prefrontal cortex acts as a modulator between the hippocampus and amygdala (Johansen et al., 2009). In the prefrontal cortex, neurons that are active during the delay interval between a stimulus presentation and a response in memory processes, get modulated by dopamine (Johansen et al., 2009). This shows that dopamine release, brought about by reinforcement-related activity of dopamine cells, is critical for learning on the basis of positive reinforcement (Beninger & Miller, 1998). Another consistent finding is that of an overall brain size reduction in people with ADHD, until adolescence (Tripp & Wickens, 2009). This finding is especially consistent in certain brain regions such as the caudate nucleus and several parts in the corpus callosum (Valera et al., 2007). The caudate nucleus and globus pallidus both contain a high density of dopamine receptors (Swanson et al., 2007), which might also explain the dysfunction in dopaminergic transmission in people with ADHD. Methylphenidate and other amphetamine-based psychostimulants are based on the hypothesis that they act by blocking the reuptake of these neurotransmitters in the prefrontal cortex, reducing ADHD symptoms (Stahl, 2010). The DTD specifies that methylphenidate increases the magnitude of the anticipatory dopamine cell response to predictive cues, and so decreases ADHD symptoms involving the reward-system.

Medication based treatments have been considered first line treatments in most western countries. Findings from the National institute of Mental Health Multimodal Treatment study of Children with ADHD (MTA) suggest that a medication management plan in combination with treatment show an advantage for ADHD outcomes over behavioral and community care. However, looking at other functional outcomes such as academic performance, aggression and social skills; approaches in combination with behavioral/community care might be preferred. Still, there is a large discrepancy between what is anticipated of children in community care and what yields greatest success (MTA Cooperative Group, 2004). Demands of community care are often burdensome. Moreover,

medicine based treatment comes with multiple side-effects like decreased appetite, sleeping problems or personality changes. Often, these side-effects lead to discontinuation within one year (Toomey et al., 2012). Thus, additional intervention options are needed to cover these issues.

Currently, research for alternative interventions is growing steadily. One of these alternative approaches, which is also recognized in many European countries, is physical activity. It has been proven that exercise is beneficial for cognitive performance in children (Sibley & Etnier, 2003). Early research on this subject was largely focused on later adulthood, where physically active lifestyles and aerobic interventions were connected to the preservation and enhancement of cognitive function, especially executive functions (Mehren et al., 2019). Recent human studies also suggests that aerobic physical activity enhances frontal brain structure and function. Such findings are relevant to ADHD because executive function deficits, especially inhibition challenges, are other core impairments associated with ADHD (Barkley, 1997). Importantly, ADHD symptoms extend beyond executive function deficits. In a study by Taylor et al. (2019) it was found that exercise reduces several ADHD symptoms in children (age 10-11), including impulsivity and distractibility. This research consisted of several weeks of moderate to high intensity exercise, which was performed on school grounds. These exercises were selected by sports scientists and sports psychologists to be engaging and to enable a moderate to intense-work rate. In other words, research involving exercise can be implemented in school settings without disturbing regular education.

Another alternative approach in the ADHD research is video games. Over the years, technology has become an indispensable tool in our society. Video games have become the favourite leisure activity of children nowadays. Video games could therefore be a good way of getting children’s attention for therapeutic interventions. Playing video games is prevalent in both children with and without neurodevelopmental disorders (Mazurek & Engelhardt, 2013). It has been found that playing video games can train some executive functions, including top-down attention and flexibility (Bavelier, et al. 2012). This might be beneficial for children with ADHD whose executive functions are lacking because of an alteration in

dopaminergic functioning. The effect of video games on attention has not been widely studied, although it is known that people with ADHD can focus for long periods of time on activities they enjoy, which is called hyperfocus (Ashinoff & Abu-Akel, 2019). Especially with video games, children with ADHD tend to draw all their attention to a game they really enjoy while they are normally highly distractible (Goodwin & Oberacker, 2011). Most research about video game intervention and their effect on attention in children with ADHD involves 'serious games' (Peñuelas-Calvo et al., 2020). In these studies the cognitive training that was used, reduced the ADHD symptoms after a few weeks of playing the games. But they did not focus solely on attention and most of these games were performed on a Personal Computer (PC), which requires the children to sit still.

A suitable intervention that combines both games and exercise, would be exergames. Exergames are video games that require physical exercise to play, like strength, balance and flexibility activities (Oh & Yang, 2010). These games have been designed to increase the enjoyment and motivation of physical exercise by reducing the boredom of repeated physical activities. Enjoyment is an important factor for children with ADHD to get into a state of hyperfocus. This indirectly leads to cognitive benefits due to the increasement in exercise. Even though exercise and games have a positive effect on children with ADHD, research on the effect of exergames on ADHD is scarce. Tsimaras et al. (2014) have performed an interactive game intervention in individuals with ADHD after which symptoms of distractibility and hyperactivity in adults were reduced. Another research by Benzing and Schmidt (2019) used an exergaming intervention to improve executive functions in children with ADHD. Their study produced positive effects regarding inhibition and switching between two tasks, and additional enjoyability. In this study it is especially interesting that switching between two tasks has improved due to a exergame intervention, because switching is originally an attentional task. It would be interesting to replicate this finding and focus more on attention rather than executive functions. However in general, research with exergames hardly focuses on improving attention in children with ADHD, which is thought to be at the base of other cognitive deficits (Friedman et al., 2007).

Therefore, the main aim of this study is to investigate the effects of an exergame intervention on attention in children with ADHD. In this study we used Wii-fit games, which required the Wii-Fit Balance board (Nintendo®). The aim of this study is to test the effect of Wii-Fit intervention on the attentional abilities of children with ADHD. Secondly, we tested whether the level of physical activity of a child is related to the level of learning during the intervention. It might even be that children who exercise more regularly already have an higher level of cognitive functioning than children who do not exercise outside of school (Sibley & Etnier, 2003). Finally, we tested whether the children who had medication learned more during the intervention compared to the children without medication. This is because ADHD medication might already cause a different baseline for children who use medication than for children who are not on medication.

2. Methods

2.1 Subjects

Criteria for inclusion in the intervention group were children aged between 8 and 13 years old, who were diagnosed with ADHD or had ADHD symptoms. A list of children was composed by a special needs coordinator from a primary school for special education in the Netherlands. Seventeen Dutch children, 1 girl and 16 boys, were selected from this list and permission was validated from parents and caretakers. Eleven children were on medication while starting the assessment. The only medication that was used was methylphenidate.

2.2 Instruments and apparatus

2.2.1 Demographical information

Before the assessment started, the children were asked to answer a list of demographical questions. The demographical information consisted of name, age, gender, date of birth and additional information. Such as, the number of hours spent on sports and gaming, if the children were diagnosed for ADHD and if they used medication. Table 1 lists the demographical information that has been used in this study.

Table 1

Demographical information

	N	Minimum	Maximum	Mean	Std. Deviation
Age	17	8	13	10.94	1.30
Height	17	135	168	149.76	9.93
Weight	17	24.0	69.5	42.28	14.79
HrsSport	17	1	8	3.76	1.92

Note: Demographical information essential for the Wii-fit games.

2.2.2 The Test of Everyday Attention for Children (TEA-CH-NL)

The Dutch edition of the Test of Everyday Attention for Children (TEA-CH-NL) was used to test the children's attention level (Manly et al., 2001). The TEA-CH-NL is a standardised and norm referenced test that is validated for the Dutch population of children aged 6 – 16 years. The test consists of 9 subtests which focus on assessing different variants of attention, including: selective attention, vigilance, divided attention, switching and response inhibition. The subtests have a playful design, 5 out of 9 subtests are auditory and measure sustained attention, switching and response inhibition. Two out of the auditory subtest are double-tasks, which combines an auditory task with a visionary task. The TEA-CH contains two parallel forms, part A and part B, which make retests with children possible. The test-retest reliability coefficients of eight variables have a value of 0,69 and higher. This indicates that most sub-tests are very reliable for interventional use.

2.2.2.1 Ruimsteschepen: In this subtest the children had to search for matching pairs of spaceships amongst multiple rows of random different or identical pairs of spaceships on a big piece of paper. The children only had to encircle the pairs of spaceships

which were identical, as fast as possible. For this subtest, time was recorded and the number of correct, identical pairs were counted. To correct the data for motor problems or motor performance, a different piece of paper was offered separately, which only contained identical pairs of spaceships. The identical pairs needed to be finished as fast as possible, since time was also measured. “Ruimteschepen” (RS) tested selective attention. Attention was measured by measuring the time the child needed to detect the identical pairs between the distracting pairs, corrected for the time the hand of a child needed to encircle the identical pairs. When a child needed less time to target identical pairs, performance increased.

2.2.2.2 Tel mee: This subtest required the children to count videogame sounds. In this subtest a CD-player is required. The videogame sounds were divided over 10 parts. Each part consisted out of a certain amount of video-game sounds, each were played in a different sequence. The children had to listen carefully to each part to count the right amount of videogame-sounds. This subtest lasted for approximately 15 minutes. “Tel mee” measures sustained attention. The subtest was measured by counting the number of correct answers the child gave to every part. Raw scores are converted into standardized scores corrected for age.

2.2.2.3: *Ruimteschepen dubbeltaak*: This subtest combines the two subtests mentioned above. The children had to search for identical pairs of spaceships and simultaneously listen for videogame-sounds. In this subtest however, the children could stop counting videogame-sounds as soon as they finished the spaceship task. The scores consisted out of the time for the spaceship task as well as the amount of videogame-sounds the children had counted and the amount of identical pairs the children had encircled. This subtest measures both sustained attention as divided attention. Attention was measured by comparing the performance of the children on this subtest with the performance on ‘Ruimteschepen’ and check how much their performance decreased when another task would be added in this subtest of ‘Ruimteschepen Dubbeltaak’. The score on this subtest is called ‘Ruimteschepen Prestatiedaling’.

2.2.2.4.: *Loop, sta stil*: In this subtest the children had to follow a certain path of footsteps on a large piece of paper. On a CD-player a track was played with sounds of footsteps and also a special sound for a “wrong footstep”. Each step had to be marked on the piece of paper. As soon as the “wrong footstep” is heard the child had to prevent themselves of marking the next footstep. On the piece of paper, 20 paths of footsteps are to be followed. Response inhibition is measured by looking at each path and check if the child managed to stop in time after hearing “wrong footstep” signal. Besides response inhibition, sustained attention was also measured in this task. Raw scores consisting out of the number of correct paths are converted into standardized scores (Loopstastil_correct).

2.2.2.5 : *Omgekeerde wereld:* In this last subtest, the children needed to discriminate numbers between the “echte wereld” and the “omgekeerde wereld”, in other words the real world and the opposite world. The numbers 1 and 2 were written in a booklet, which was part of the TEA-Ch. In the “echte wereld” a tester pointed at the numbers and the children had to name the numbers as they are. So number 1 is 1 and number 2 is 2. In the “omgekeerde wereld” a tester points at the numbers, but the children now have to name the numbers reversed. So number 1 is 2 and number 2 is 1. The amount of time the children needed to name all the numbers in the different ‘worlds’ was measured. This subtest is based on attentional switching. The amount of time the child uses to make a cognitive switch is the essential value of this test. Raw scores consisting of the time in seconds the children needed to finish the “echte wereld” (Echtewereld_time) and the “omgekeerde wereld”, are converted into standardized scores (Omgekeerdewereld_time).

2.2.3 Wii-Fit Balance

The Nintendo© Wii is an interactive video computer system that has been combined with a Balance board. The balance board has a Bluetooth wireless connection and is battery operated. The game Wii Fit Plus was played by using the balance board, remote controller and nun chucks. The balance board has four force plate sensors, one in each corner, used to measure the child’s weight, and to calculate the centre of pressure (COP) and weight

distribution. When the child is standing on the board it can steer the virtual character/Avatar, called Mii, by moving the Centre of Mass sideways or forward and backward. The Wii Balance board software calculates the COP of these displacements, resulting directly in the movements of the Mii. Five games of Wii-Fit Plus have been used in this research, including: Soccer heading, Kungfu, Juggling, Table tilt, Tilt city and Zazen.

2.2.3.1 Soccer heading: The goal of the game is to head as many balls as possible to get points and avoid soccer shoes and panda's to prevent losing points. This is done by shifting the centre of mass to left and right on the Balance board. This game represents selective attention and response inhibition in the assessment of attention. The child has to focus on the task of heading the soccer balls, but they have to inhibit the urge to react to other stimuli such as shoes and panda heads.

2.2.3.2 Kungfu: In Kungfu the child has to mimic the movements that the other Mii-characters on the screen make, in a certain rhythm. These movements consist of punches and kicks. Four other Mii-characters, besides the child's Mii-character are presented on the screen and they perform the movements first. The movements can be rated as 'ok', 'perfect' and 'miss'; this was judged according to the correct rhythm that the child followed and if the right movements were performed. The nun chuck was required to play this game, because both arms were needed. In this game response inhibition was tested, since the children have to resist to react instantly and need to wait for the right moment to act out the movements.

2.2.3.3 Juggling: In Juggling the child has to balance their Mii-character on a ball and simultaneously juggle balls in the air by using the nun chuck and Wii remote. The child can balance on the ball by shifting their centre of mass to the left and right. Juggling is performed by making juggling movements with both arms by using the nun chuck and Wii remote. The child starts with one ball and the longer you keep the ball in the air the more balls you get to juggle. The game takes place in a circus. If the Mii-character gets too close to the edge of the circus ring, the character will not be able to juggle balls. Points can be gathered by holding a ball in the air as long as possible, the more balls you juggle the more points you get. This

game requires the children to divide their attention to balancing the Mii-character on the ball and juggling balls in the air.

2.2.3.4 ***Table Tilt:*** In Table tilt the child has to roll marbles into holes by shifting their centre of mass on the balance board. By shifting the centre of mass forwards, backwards, left and right, the child tilts the platform that holds the marbles. Table Tilt consists of multiple levels, the more levels you pass the more points you get. Each level gets harder, because more marbles are added or the platform gets more complex. The child passes a level by rolling all the marbles into a hole within a limited amount of time. When reaching a next level extra time is added. This game tests selective attention and divided attention, since the children have to select which marble they have to focus on and also divide their attention to the other marbles to prevent them from rolling over the edge.

2.2.3.5 ***Tilt City:*** In Tilt City the child has to put coloured marbles into coloured pipes by moving two different platforms. The platforms can be controlled by the Wii remote, which has to be hold horizontally so it can be tilted downwards, and the balance board by moving sideways. The two platforms have been placed vertically distanced from one another on the screen. The marble needs to go from one platform, controlled by the Wii remote, to the other platform, controlled by the balance board, into the coloured pipes. Each coloured marble needs to go into their colour-matched pipe, to receive points. The more marbles they consecutively move into their matching pipes, the more points the children earned. This game required divided attention, hand-eye coordination and planning capacity to the different platforms they controlled.

2.2.3.6 Zazen: The game Zazen requires the child to sit still on the balance board in the same position, preferably cross-legged, for as long as possible. On the screen a candle is shown, but when the child started moving too much the candle will be blown out. The longer you are able to keep the candle lit, the more distractions the game presents. Distractions can consist of noise or visual distractions, like a butterfly on the screen or

footsteps on a creaking floor. The duration of the candle being lit is measured in seconds. This game requires the children to sustain their attention on one task as long as possible.

2.2.4 Enjoyment Scale

An enjoyment scale of 5 points with smiley faces (0 is no fun at all; 4 is super fun) was used for this study to evaluate how much the child enjoys playing the Wii games at a certain moment in time (Jelsma et al. 2014).

2.2.5 SDQ

The Strengths and Difficulties Questionnaire (SDQ) is a brief questionnaire developed by Goodman (Goodman, 1997) for assessing the psychosocial adjustment of children and adolescents. The Dutch version of The Strengths and Difficulties Questionnaire was given to the parents and/or caregivers of the children. The SDQ contains 25 items that are divided into five scales: emotional symptoms, conduct problems, hyperactivity-inattention, peer problems, and prosocial behavior. All items fit onto one page and concern both strengths and difficulties. The inter-informant product-moment correlations of the Dutch translation are satisfactory (parent-teacher 0.38; teacher-self-report 0.27; parent-self-report 0.35) (Widenfelt et al. 2003).

2.2.6 TRF (CBCL)

The Teacher Report Form (TRF) is part of the Achenbach System of Empirically based Assessment (ASEBA; Achenbach & Rescorla, 2001). The TRF used in this study has been adapted to this study design. This form is shorter and the items that have been selected are more fitting for the children in this study, because only the subtest concerning hyperactivity/inattention was included. The complete version of the TRF has appropriate psychometric properties for the assessment of ADHD. It has a Test-retest reliability of .89 for Empirically based syndromes and .88 for Internalizing and Externalizing items. It also shows a long-term stability of .77 for Total Problems (Achenbach, et al. 2008).

2.3. Design

This study has a one-group pre-posttest design, with an intervention as the in-between assessment. The pretest was taken within one week, after the pretest three weeks of intervention followed. The intervention consisted of the Wii-games, the Enjoyment scale and a perception questionnaire which was implemented two times per week. The study ended with the posttest. This study can be considered a pilot study for feasibility for using Wii-games as an intervention to improve the attention of children with ADHD. This intervention study was approved by the Ethical Committee of Psychology of the University of Groningen (PSY-2122-S-0345).

2.4. Procedure

First, all the children were tested on their attention with the TEA-CH-NL by two testers. All children were tested individually, this assessment included a questionnaire for demographical information. While the children performed the TEA-CH, the testers recorded notable behavior in a logbook. Before the intervention started, the TRF was given to teachers to fill in and the SDQ was given to parents. The second step was performing the intervention. The intervention consisted of five Wii-Fit sessions spread out over three weeks. In the first session a Mii-character was created for every child and the balance board was calibrated for the child's height, measured by the testers, and weight measured by the Balance board. Subsequently, all children completed the Wii basic balance test in order to get acquainted in a standardized way with steering the Mii. Every session compromised the same six Wii-fit games. The children performed the games, led by the two testers, in couples and some of them individually. During the games, the testers recorded the scores of the game of each individual child. After they played the games, the children had to score the Enjoyment scale and additional questions about how much they enjoyed the games on a scale of 1 to 5. Besides the Enjoyment scale, the children had to answer a questionnaire containing questions on perception. These questions aimed to gather information regarding auditive and visual effects that grabbed the children's attention and whether they got distracted by these

effects. During the intervention the SDQ and TRF were given back to the testers, filled in by the parents and teachers. Afterwards, a second assessment of the TEA-CH was performed by the children. Their behavior during the test and training was again recorded in a logbook by the testers.

2.5 Statistical Analysis

In total, 17 children participated in the intervention. For the demographical data see Table 1. The mean age of this group was 10,94 (*SD*= 1.298). All the raw scores of the TEA-CH subtests have been converted to Standardized Scores (SS) to account for age differences. The TEA-Ch variables, Ruimteschepen Attention scores (RS_Attention), Telmee, Ruimteschepen Dubbeltaken Prestatiedaling (RS_DT_PD), Loopstastil_correct, Echtewereld_time, Omgekeerdewereld_time were used in this study. First data was checked for normality, by using the Shapiro-Wilk test for Normality, and outliers by studying the descriptives and frequencies of the TEA-Ch subtests, Wii-Fit games and the B1 results of the Wii-Fit games (see Appendix 1). To analyze if the intervention had an impact on Attention in children with ADHD, the pre and post standardized scores of the TEA-CH subtests were calculated to test for differences. If normality was presented for the subtests, a paired samples T-test was done with the Standardized Scores of the Pre and Post TEA-CH. If normality was not shown, the Related Samples Wilcoxon Signed Rank test was used to compare the Pre and Post TEA-CH subtests. Learning curves have been plotted over various weeks, a learning curve shows the mean learning capacity of a child. These curves have a certain steepness which shows how fast a child learns. For every Wii-Fit game a coefficient of the learning curve has been determined. These have been summed up over 6 Wii-Fit games and 5 session and a mean has been taken.

For the second research question, the children were divided in two groups of PAcategory. The two groups were divided according to the Dutch exercise guidelines (https://www.rijksoverheid.nl). Therefore children who exercised more than 3 hours per week were included in the PAhigh group, the other children who exercised 3 hours or less per

week were included in the PAlow group. A Mann-Whitney U test was performed to test for differences between the PAlow – and PAhigh group of the Wii-fit game scores over time. The first and fifth session were used of every game as the dependent variable, the independent variable was PACategory. Within the PA groups the differences in performance between the first and the last session was tested by using the Wilcoxon Signed Rank test. Additionally, the relationship between the hours of sports and the learning curve of the children was tested with a Spearman rank correlation. The B1 results in Appendix 1 represent the steepness of the learning curve in the correlation.

For the third research question, the children were again divided in two groups but now according to medication. One group consisted of children who take medication to reduce their ADHD symptoms, the other group consisted of children who do not take medication for ADHD. The children who take medication are grouped together because they all take Methylphenidate-based medication. Mann-Whitney U tests were performed to tests for differences between the two groups in the Wii-fit game scores over time, by taking the first and fifth session as the dependent variable and the Medication as the independent variable. Within the groups the difference in performance between the first and last session was also tested by using the Wilcoxon Signed Rank test.

3. Results

3.1 Effect of the intervention

Of the 17 children who started the experiment, only 15 children completed both the screening and intervention. There are some missing data in the Pre-and Post Teach, as a result of children who stopped with the intervention or were not present on the post-test measurement days and in some cases the testers forgot to measure time. It has been decided to include these missing data in the results. The Shapiro Wilk tests for Normality were all non-significant, except for the Converted scores in the RS. The Related Samples Wilcoxon Signed Rank test showed a statistically significant decrease in the RS Converted scores from Pre- to Post Teach ($Z= -2.229$, $p = 0.026$). This significant decrease is an improvement in performance. Paired sample t-tests showed no differences between the other TEA-CH subtests Pre- and Post Standardized Scores (all $p>0.05$; see table 2).

Table 2

Statistical analysis testing the differences in mean scores between the Pre-Post TEA-Ch subtests within a sample of 15 children with ADHD

	Pretest M. (SD.)	Posttest M. (SD)	Stat. Analysis (t-test/Wilcoxon)	Sig.	Cohen's d
RS_Attention	4.47 (1.73)	3.55 (1.32)	-2.229 (Z)	0.03	
Telmee	6.93 (2.92)	5.80 (2.21)	1.73 (t)	0.11	0.45
RS_DT_PD	7.79 (3.83)	6.29 (3.17)	1.50 (t)	0.16	0.40
Loopstastil_C	8.47 (3.02)	8.93 (4.18)	-0.63 (t)	0.54	-0.16
Echtewereld_T	6.47 (3.00)	6.87 (4.18)	-0.56 (t)	0.58	-0.15
Omgekeerde wereld_T	6.13 (4.16)	7.53 (4.52)	-1.72 (t)	0.11	-0.44

*Note. RS_Attention: a decrease in score equals an increase in performance; Telmee: an increase in score equals an increase in performance; RS_DT_PD = Ruimteschepen Dubbeltaken Prestatiedaling: an increase in score equals a decrease in performance; Loopstastil_C = Loopstatstil correct: an increase in scores equals an increase in performance; Echtewereld_T = Echtewereld Time: an increase in score equals a decrease in performance; Omgekeerdewereld_T = Omgekeerde wereld Time: an increase in score equals a decrease in performance ** p < .05*

3.2 Effect of exercise on the intervention

To check if the limit set for allocating the children in different groups of PA was valid, a T-test was used to check if there was a significant difference. This test showed that there is a significant difference (t (15) = -6.87; $p < 0.001$) in hours of sports between the PAHigh (M = 5.50; SD = 1.20) and PAlow group (M = 2.22; SD = .67). In the PAHigh group, one child dropped out during the intervention, the groups were still valid after the droup-out. Mann-Whitney U tests were performed, to determine if there was a statistical difference between the PAhigh and PAlow groups in the performance of the Wii-fit games. No differences were found in the Wii Fit scores between the PA High group and PALow group in the first nor in the fifth session. Table 3 lists the results of the Mann-Whitney U tests.

Table 3

The differences in Wii-fit game scores between the PA categories within the first and last trainingsessions

Wii games	Session 1				Session 5			
	PAHigh (SD)	PALow (SD)	U.	p-value	PAHigh (SD)	PALow (SD)	U.	p-value
Soccer	19.25 (13.41)	15.44 (6.13)	35.50	.96	61.86 (44.058)	46.13 (33.70)	19.50	.34
Kungfu	208.57 (89.89)	255.71 (99.31)	18.00	.41	382.86 (117.43)	445.00 (120.59)	22.00	.54
Juggling	32.25 (25.38)	32.38 (29.80)	30.50	.88	245.86 (243.05)	310.88 (256.81)	25.00	.78
TableTilt	27.50 (16.69)	32.50 (19.09)	29.00	.75	35.71 (12.72)	35.00 (16.90)	27.00	.96
TiltCity	42.38 (31.88)	49.63 (26.12)	28.00	.67	76.00 (30.55)	72.50 (44.87)	22.00	.54
Zazen	47.63 (26.09)	37.13 (20.24)	17.00	.11	57.33 (47.52)	30.13 (3.36)	12.50	.14

Note. Wii-games = totalpoints of each game. Higher score indicates better performance. No significant p-value.

p < .05

Within-group improvement has been found within the PAHigh as well as the PALow group by using Wilcoxon Signed Rank tests, here the change scores from the first session to the fifth session were tested. The PAHigh group showed a significant improvement in scores from the

first session to the last session for Soccer (*Z* = -2.37, *p*= .018), Kungfu (*Z* = -2.20, *p* = .028), Juggling (*Z* = -2.37, *p* = .018) and Tiltcity (*Z* = -2.20, *p* = .028). The PALow group also showed a significant improvement from the first to the last session in Soccer (Z = -2.24, *p* = .025), Kungfu (*Z* = -2.37, *p* = .018) and Juggling (*Z* = -2.52, *p* = .012). No significant differences in scores between the first and the fifth session for both groups were found for Tabletilt and Zazen.

Spearman's rank correlation showed no significant correlations between the steepness of the learning curve of the Wii-fit games during intervention and the hours of sport.

Table 4

Spearman rank correlation between hours of sports and learning curve Wii-fit game scores

	HrsSport	Soccer	KungFu	Juggling	TableTilt	Tiltcity	Zazen
HrsSport	_						
Soccer	-.024	_					
KungFu	.160	.176	_				
Juggling	-.166	.464	.090	_			
TableTilt	.275	.082	.387	-.172	_		
TiltCity	.436	.066	.049	.194	.269	_	
Zazen	-.019	-.011	-.004	-.013	-.286	.302	_

Note: HrsSport: Hours of sports of the children per week estimated by the testers. Wii-fit games: B1 results from Appendix 1. No significant correlations. p < .05

3.3 The impact of medication on the effect of the Wii-fit games

In the first session there was a significant difference (Z = -2.11, p = .041) in performance between Medication and No-Medication for the Zazen game, the No-Medication group performed better than the Medication group. In the last session a significant difference in performance was found in Tiltcity (Z = -2.12, p = .034). Here, the No-Medication group again performed better than the Medication group. The Medication group showed a significant growth between the first and the last session in Soccer (Z = -1.572, p= .008), Kungfu (Z = -2.52, p = .012) and Juggling (Z = -2.20, p = .028). The No-Medication group also showed a significant growth in Kungfu (Z = -2.02, p = .043), Juggling (Z = - 2.20, p = .028) and Tiltcity (Z = -2.20, p = .028). No differences between sessions were found in Tabletilt and Zazen in both groups.

Table 5.

The differences in Wii-fit game scores between the Medication categories within the first and last trainingsessions

Wii games	Session 1				Session 5			
	Med. (SD)	No-med. (SD)	U.	p-value	Med.	No-med. (SD)	U.	p-value
Soccer	17.82 (12.16)	16.17 (5.12)	30.50	.80	57.22 (32.56)	47.83 (48.42)	19.50	.39
Kungfu	233.33 (92.20)	230.00 (108.86)	21.50	.89	443.33 (130.96)	375.00 (94.81)	17.00	.27
Juggling	32.40 (29.43)	32.17 (24.21)	29.50	.96	230.33 (194.919)	355.83 (307.00)	21.00	.53
TableTilt	29.00 (16.63)	31.67 (20.41)	26.00	.66	40.00 (13.229)	28.33 (14.72)	15.00	.18
TiltCity	46.00 (26.02)	46.00 (34.66)	27.50	.79	63.11 (41.02)	90.67 (26.63)	9.00	.04
Zazen	31.00 (2.79)	61.33 (30.18)	11.00	.04	32.50 (8.16)	54.17 (48.64)	16.00	.35

Note. Med. = Medication-group, No-med.= No-medication group. $p < .05$

Discussion

The aim of this study was to investigate the effects of an exergame intervention on attention in children with ADHD. In this study we used Wii-fit games. The aim of this study is to test the effect of Wii-Fit intervention on the attentional abilities of children with ADHD. Overall, there was a trend of improvement after the intervention but these were not significant, except for the Attention score in the subtest ‘Ruimteschepen’, which measures selective attention. Secondly, we tested whether the level of physical activity of a child is related to the level of learning during the intervention. Between the PAHigh and PALow group no significant difference was found in performance of the Wii Fit games over 5 sessions. There was also no relationship found between the number of hours doing sports and the learning curve of the Wii-Fi games. Within the groups significant there was significant improvement from the first session to the fifth in both the PAhigh and PAlow group for a few selected games. Finally, we tested whether the children who had medication learned more during the intervention compared to the children without medication. When looking at use of medication, a difference was found between children using medication and children who do not use medication in performance of the Wii-fit games. In the first session of performing the Wii-fit games there was a significant difference in performance of Zazen and in the last session there was a significant difference in performance of Tilticity. Both these differences were in favour of the group who did not use any medication for ADHD symptoms, they performed significantly better than the group who used medication.

When looking at the TEA-Ch attention scores it is interesting to see that the children performed slightly better on the second assessment compared to the first assessment. Especially, because during the second assessment it was noticeable that the children were less motivated. Motivation is an important factor in interventions for children with ADHD (Modesto-Lowe et al., 2013). Especially because it is theorized according to Tripp and Wickens (2008) that children with ADHD have problems with learning through positive reinforcement, but also prefer small immediate rewards over larger delayed rewards. During

the TEA-Ch assessments it was observed in the second assessment that it took the children more effort to concentrate on the tests. They were easily distracted by noise around them or distracted themselves by asking the testers a lot of questions not involving the tests. Other studies also report that a deficit in the reward system within children with ADHD effects motivation and attention (Volkow et al., 2011). There was also one test which showed a significant improvement in performance. This test called ‘Ruimteschepen’ measures selective attention and the children scored significantly higher on the second assessment even when controlled for motor problems. Which may be an improvement in selective attention after intervention. Few studies have been done using an exergame intervention to improve attention. More research should be done including control groups and bigger sample sizes to gain more insight about the effect of the intervention. The duration of the study might also have been too short to find more results in attentional abilities. Adding follow-up assessments and interventions might increase the validation of this study.

No relation was found between the hours of sports of the children and the level of learning the Wii-Fit games. It was assumed that children who were doing more sports should do better at the Wii-fit games, which were selected for their attentional challenges. This assumption was based other research containing sports interventions, where children with ADHD symptoms who spend more time doing sports had better executive functions (Tan et al. 2016) and showed reduced ADHD symptoms (Taylor et al. 2019). Attention is at the base of executive functions and other higher-order cognitive functions. Interestingly, no significant differences in performance of the Wii-fit games have been found between the children who have more hours of sports and the children who do not. There were also no big differences between the two groups in the first session. The children who do spend a lot of time doing sports might compensate their lack of physical training with their experience in gaming. It might also have been the case that the physical games, like soccer heading and Kungfu were not that physically demanding. In future research it might be beneficial to increase the intensity of the physical games, to check if it makes a difference for children who spend a lot

of time doing sports. Although no significant differences were found between the two groups, within the groups there were significant differences over time. Both groups grew significantly in performance from the first session to the last session. This growth has been found specifically in Soccer, Juggling and Kungfu for both groups. In the PAHigh group there was also an significant improvement from the first to the fifth session Tiltcity. All of these games require active participation and movement of the children. On top of that, Soccer and Kungfu both required inhibition of the children. According to research, mastering inhibition improves the most in children with ADHD when performing in an exercise intervention (Chang et al. 2012; Benzing & Schmidt, 2019) .The other games, (Tabletilt and Zazen) were mostly static in performance and required a lot of patience and concentration from the children. It might be interesting to check with a control group, consisting of typically developing children divided in groups of PAHigh and PALow, if they get the same results. Another reason why the active games show more growth in performance, might be because the children are more motivated when playing these kind of games. In the current study enjoyment was not included in the analysis, even though literature has shown that motivation plays an important role in children with ADHD (Modesto-Lowe et al., 2013). In future studies, more research is required for the relationship between enjoyment and the performance in Wii-fit games. It would also be interesting to check which would have more impact on ADHD symptoms, exercise or exergames. For the reason that both interventions show results in motivation and reduce ADHD symptoms, but there has been no research yet that distinguished the effect of these interventions.

In the case of medication, there have been some differences in performance in the Wii-fit games between children who use medication and children who do not. Particularly the children who did not use medication performed significantly better at Zazen in the first session, and Tiltcity in the last session, compared to the group who dó use medication. These games both require vigilance, this could indicate that not taking any medication improves the attention of the children. In an study by Medina et al. (2010), it was also tested

if methylphenidate had an impact on attention after an exercise intervention. This study showed that an improvement of attention/vigilance was not dependent of medication, the effect of exercise was enough to normalize symptoms of impulsivity and vigilance measures. The same results might be found in these exergame results but, more research is required with bigger sample sizes and more follow-up interventions to check if these findings are valid. On the other hand, the Medication group showed a steeper growth within the group from the first session to the last session, compared to the group who do not take any medication. Again, the children showed more improvement in the active games, Soccer, Kungfu and Juggling than the static games (Tabletilt and Zazen). ADHD medication is known for blocking re-uptake of dopamine. Dopamine increases attention, motivation and interest but can also lead to side-effects such as insomnia, headaches, increased blood pressure and heart rate. Most research has proven that ADHD medication, for example Methylphenidate, improves the behavior of children with ADHD over a short period of time (Schachter et al. 2001; Kimko et al. 1999).

Limitations

For the whole study it is important to point out that a control group was lacking. In other words, a group that showed homogeneity was studied to answer the research question. Within this group there were no significant outliers, their scores for attention and the Wii-fit games were closely related to each other. However the group only consisted out of 17 children. Out of these 17 children hardly 15 children finished the whole assessment and intervention. Which is not a big number and could decrease the power of this study. On top of that, the group mostly consisted of boys. Only 1 girl participated in this intervention, so there was no control on gender. This might play a role in the attention scores and the scores of the Wii-fit games, because girls tend to show different ADHD symptoms than boys (Alloway et al., 2010) and can also have different cognitive deficits than boys (Stibbe et al., 2020). So the results in attentional abilities might also be different for girls than for boys. The intervention was also relatively short for an intervention study. During the intervention the testers noted

behavior of the children while performing the TEA-Ch and Wii-Fit games, such as ‘restlessness while performing the TEA-Ch’ or ‘tapping their foot/leg during the whole TEA-Ch assessment’. Yet, no system of coding has been made for the various behavioral acts. Even though, the behavior showed a lot about the children’s motivation and enjoyment of the intervention. Another scale of motivation could be a rating of which game was the most enjoyable. Their behavior might also have been different if the intervention was performed individually with each child instead of in duo’s, because during the intervention the children showed a lot of competitive behavior. Which causes more distraction from the actual intervention and might have interfered with the results. Other research has pointed out that people with ADHD perform better when driven individually (Chang et al. 2012).

Future research

For follow-up studies it is important to extend the intervention. To include more assessments and other intervention moments, but also a control group as mentioned before. The control group should include typically developing children of the same age as the children with ADHD symptoms and have a relatively equal distribution in gender in both the clinical group as the control group. It might also be interesting to check which would have more impact on ADHD symptoms, exercise or exergames. In other words, check if games have a different impact on children with ADHD than exercise. Furthermore, it is important to check how much medication affects children with ADHD in their behavior. Within ADHD it is especially meaningful to evaluate interventions because of the side-effects and the corresponding adherence some ADHD medication causes. Interventions including exercise and/or games would also be cheaper and more accessible for most children and their families. Furthermore, it would be essential in future studies to check for enjoyment and/or motivation. This might be done by taking notes of behavior and making codes of particular behavior for the children with ADHD.

Conclusion

Taken together, an exergame intervention including Wii-fit games shows promising results for future research into ADHD interventions. Especially because there was a slight improvement in the attention values from the first assessment to the last assessment. It has also been found that hours of sports are not related to the learning abilities of children with ADHD. More research is needed to confirm these results and check if there is a difference between clinical groups and a control group. Enjoyment and motivation should also be inspected further in future research, due to the important role it plays in children with ADHD. Furthermore, this intervention showed that children without medication sometimes perform better than children with medication. This pilot-study has shown a careful step towards a future for children with ADHD, where medication might not be a first-line treatment. It is also a promising step for intervention studies, which should be evaluated more in the future to get a diverse view of ADHD.

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Appendix A

Table A1

Model summary and parameter estimates of the Total points of the Wii-fit game Soccer

Code	Model summary			Parameter estimates	
	R Square	F	Sig.	Constant	B1
KIM01	0.74	8.63	0.06	-34.30	28.50
KIM02	0.65	5.48	0.10	3.30	5.30
KIM03	0.84	15.63	0.03	5.10	8.50
KIM04	0.22	0.28	0.69	17.33	13.50
KIM05	0.74	8.60	0.06	-6.30	24.10
KIM06	0.44	2.32	0.23	5.60	2.60
KIM07	0.16	0.59	0.50	16.20	3.60
KIM08	0.65	5.48	0.10	15.30	5.30
KIM09	0.40	1.99	0.25	10.10	8.90
KIM10	0.54	3.51	0.16	9.40	11.00
KIM11	0.17	0.63	0.49	19.90	4.90
KM001	0.28	1.15	0.36	14.80	5.00
KM002	0.16	0.59	0.50	21.30	-1.30
KM003	0.49	1.95	0.30	20.00	28.50
KM004	0.27	1.10	0.37	18.90	3.70
KIM005	0.89	23.11	0.02	-31.50	27.90
KIM007	0.16	0.57	0.51	14.00	5.40

Table A2

Model summary and parameter estimates of the Total points of the Wii-fit game Kungfu

Code	Model summary			Parameter estimates	
	R Square	F	Sig.	Constant	B1
KIM01	0.65	5.63	0.10	256.00	50.00
KIM02	0.79	11.13	0.05	37.00	31.00
KIM03	0.02	0.04	0.85	355.00	-5.00
KIM04					
KIM05	0.69	6.74	0.08	236.00	56.00
KIM06	0.77	9.88	0.05	61.00	71.00
KIM07	0.29	0.82	0.46	252.00	23.00
KIM08	0.80	12.03	0.04	209.00	47.00
KIM09	0.54	3.50	0.16	300.00	46.00
KIM10	0.82	13.76	0.03	352.00	68.00
KIM11	0.73	8.22	0.06	234.00	50.00
KM001	0.58	4.13	0.14	321.00	51.00
KM002	0.79	11.31	0.04	72.00	28.00
KM003	0.83	9.71	0.09	95.00	86.00
KM004	0.91	30.67	0.01	234.00	62.00
KIM005	0.68	6.25	0.09	118.00	46.00
KIM006	0.00	0.01	0.94	398.00	2.00

Table A3

Model summary and parameter estimates of the Total points of the Wii-fit game Juggling

Code	Model summary			Parameter estimates	
	R Square	F	Sig.	Constant	B1
KIM01	0.58	4.13	0.14	6.80	39.80
KIM02	0.83	14.57	0.03	3.50	12.90
KIM03	0.95	52.02	0.01	-77.10	95.30
KIM04					
KIM05	0.07	0.24	0.66	21.40	7.00
KIM06	0.84	15.40	0.03	-14.10	26.10
KIM07	0.12	0.43	0.56	32.70	3.50
KIM08	0.71	7.46	0.07	-132.40	110.60
KIM09	0.93	42.37	0.01	-147.80	160.80
KIM10	0.76	9.42	0.06	90.00	93.80
KIM11	0.94	48.22	0.01	-19.10	52.10
KM001	0.42	2.16	0.24	-47.50	49.10
KM002	0.28	1.18	0.36	4.50	3.10
KM003	0.99	307.94	0.00	-247.00	321.80
KM004	0.83	9.47	0.09	-76.17	66.51
KIM005	0.59	4.27	0.13	-52.90	54.10
KIM006	0.91	31.50	0.01	-208.90	186.50

Table A4

Model summary and parameter estimates of the Total points of the Wii-fit game Tabletilt

Code	Model summary			Parameter estimates	
	R Square	F	Sig.	Constant	B1
KIM01	0.19	0.69	0.47	19.00	3.00
KIM02	0.80	12.00	0.04	6.00	8.00
KIM03	0.20	0.75	0.45	32.00	-4.00
KIM04					
KIM05					
KIM06	0.50	3.00	0.18	-12.00	8.00
KIM07	0.64	5.42	0.10	-5.00	11.00
KIM08	0.28	1.17	0.36	55.00	-3.00
KIM09	0.32	1.42	0.32	18.00	6.00
KIM10	0.06	0.19	0.69	42.00	2.00
KIM11	0.04	0.14	0.74	42.00	-2.00
KM001	0.32	1.42	0.32	13.00	3.00
KM002	0.04	0.11	0.76	21.00	-1.00
KM003	0.55	2.48	0.26	15.00	12.00
KM004	0.13	0.43	0.56	20.00	2.00
KIM005					
KIM006	0.01	0.02	0.89	46.90	1.10

Table A5

Model summary and parameter estimates of the Total points of the Wii-fit game Tiltcity

Code	Model summary			Parameter estimates	
	R Square	F	Sig.	Constant	B1
KIM01	0.25	1.02	0.39	64.30	16.10
KIM02	0.21	0.81	0.43	28.70	9.70
KIM03	0.80	11.71	0.04	1.80	23.20
KIM04					
KIM05	0.04	0.14	0.73	67.50	5.10
KIM06	0.62	4.92	0.11	9.30	13.30
KIM07	0.08	0.26	0.65	46.00	3.00
KIM08	0.01	0.03	0.87	66.60	-1.40
KIM09	0.10	0.32	0.61	53.40	3.80
KIM10	0.00	0.00	0.99	122.40	-0.20
KIM11	0.03	0.08	0.80	59.20	5.20
KM001	0.18	0.64	0.48	30.40	3.20
KM002	0.00	0.00	0.97	53.60	0.20
KM003	0.56	2.54	0.25	7.00	40.70
KM004	0.04	0.11	0.76	54.60	4.00
KIM005	0.79	10.96	0.05	-30.60	32.60
KIM006	0.06	0.18	0.70	113.70	8.10

Table A6

Model summary and parameter estimates of the Total points of the Wii-fit game Zazen

Code	Model summary			Parameter estimates	
	R Square	F	Sig.	Constant	B1
KIM01	0.26	1.07	0.38	54.10	-4.50
KIM02	0.60	3.00	0.23	37.00	-3.00
KIM03	0.66	5.82	0.10	19.60	22.40
KIM04					
KIM05	0.13	0.43	0.56	16.70	13.30
KIM06	0.03	0.08	0.79	31.00	-0.20
KIM07	0.01	0.03	0.88	32.20	-0.20
KIM08	0.77	9.82	0.05	33.40	-1.20
KIM09	0.71	7.21	0.08	123.90	-16.50
KIM10	0.07	0.22	0.67	39.10	-1.90
KIM11	0.52	3.30	0.17	20.30	4.50
KM001	0.00	0.00	0.96	41.80	0.60
KM002	0.74	8.59	0.06	24.90	1.30
KM003	0.06	0.13	0.76	32.50	11.40
KM004					
KIM005	0.26	1.06	0.38	28.70	0.70
KIM006	0.00	0.00	0.98	70.00	0.40