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Faculteit Geneeskunde en Levenswetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

The effect of age and gender on typically developing children performing a visuo-manual tracking task

Silke Gregoire
Margot Plessers

Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie, afstudeerrichting revalidatiewetenschappen en kinesitherapie bij musculoskeletale aandoeningen

PROMOTOR :
Prof. dr. Raf MEESEN

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Finally, we offer our gratitude to our promotor – Prof. dr. Raf Meesen – to help us during the process of writing our thesis, with his knowledge and at the same time giving us the opportunity to explore the subject in our own way.

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Research context

This master thesis fits in the research domain of pediatric rehabilitation. By using a visuo-manual tracking task with accelerating target, typically developing (TD) children were examined to see if they adapt to changing target velocities. In the present study, the performance of the children was examined for 1) the effect of age in TD children and 2) the effect of gender in TD children from the same age.

Not only is eye-hand coordination of great importance in children's development of motor skills, it is also constantly used in day-to-day life (Caeyenberghs, van Roon, et al., 2009; Crawford, Medendorp, & Marotta, 2004). Therefore, it is necessary to have a method to measure eye-hand coordination in TD children. This way, improvement of insights and development can be realized in TD children from different age groups as well as in children with a (developmental) disorder. However, more data is required to use these measurement tasks as an overall screening tool.

This second part of the master thesis is a follow-up of the literature study which investigated the possible visuo-manual measurement tasks most applicable to children from 6 to 12 years old to examine eye-hand coordination. The most adequate visuo-manual tracking tasks could be applied in further research. Several visuo-manual tracking tasks were found and components such as target velocity and target size of the most adequate task were used to develop a new visuo-manual tracking task. This new tracking task was used in the current study.

This part of the thesis was written in the second master year of Physiotherapy and Rehabilitation Science at University of Hasselt in Diepenbeek. The entire master thesis was a new research project regarding eye-hand coordination evaluated in children from 6 to 12 years old.

For this study, the research design and methods were determined in cooperation with the promotor Prof. dr. Raf Meesen and with Prof. dr. Katrijn Klingels. The recruitment of the participants and data-acquisition were done independently by the two students. The data was analysed under the supervision of the promotor. The academic writing of the article was done by the two students.

This master thesis was completed in cooperation with two other master theses. Two students of industrial engineering, Jonas Vanstraelen and Ruben Debien, designed the visuo-manual tracking task in the context of their master thesis. The master thesis of Lotte Peeters and Annemart Luyten, supervised by Prof. dr. Katrijn Klingels, investigated the learning effect in children. All master theses used the same visuo-manual tracking task.

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TABLE OF CONTESTS

1 Abstract

Background: Eye-hand coordination is a major aspect of motor skills needed for the coordinated control of the combination of eye movement with hand movement. Visuo-manual tracking tasks would be an efficient and easily applicable way to measure eye-hand coordination in children.

Objectives: The aim of the present study was to examine the effect of age in typically developing (TD) children on eye-hand coordination, as well as the effect of gender in TD children from the same age, using a visuo-manual tracking task with accelerating target.

Participants: One hundred fifty-two TD children (75 boys, 77 girls) from 6 to 12 years old were included in this observational cross-sectional study.

Measurements: Participants were instructed to track an accelerating target as good as possible along a circular path in a trial of 60 seconds. Outcome measures were the mean distance between the centers of the target and cursor, standard deviation of the distance between the centers and the time the cursor spent in the target. The dependent variables were analyzed for the first and last ten seconds of the trial and for the difference between the first and last ten seconds for a better representation of the performance considering the accelerating target.

Results: The performance of the visuo-manual tracking task improved with age. Older children had a smaller mean distance and standard deviation of the distance between the centers of the target and cursor and a longer time spent in the target in comparison with younger children. The variance between age groups decreased with age for the mean distance and standard deviation of the distance. No general differences were found between boys and girls.

Conclusion: The main finding was that the overall performance of the children improved with age. However, no general differences were found between boys and girls for any age group.

2 Introduction

Eye-hand coordination is a major aspect of motor skills concerning the coordinated control of the combination of eye movement with hand movement (Crawford et al., 2004). It is an aspect used in most sports, schoolyard games and in everyday life activities. Eye-hand coordination has an important role in children's development of motor skills. (Caeyenberghs, van Roon, et al., 2009). Research shows that children with better eye-hand coordination are fitter, participate more frequently in organized sports, tend to have more positive perceptions of their physical appearance and are more likely to develop into fitter adolescents (Barnett, Van Beurden, Morgan, Brooks, & Beard, 2008; Telford et al., 2013).

A combination of feedback and feedforward control strategies is required in motor performance (Desmurget & Grafton, 2000; Wolpert & Miall, 1996). Feedback control strategy depends on sensory feedback, error detection and integration (Scott, 2012). Feedforward control strategy concerns an estimation of temporal and spatial requirements of a motor performance and a prediction of the consequences of the prospective motor action (von Hofsten, 2007; Vonhofsten, 1993; Wolpert & Miall, 1996). The foundation of this predictive strategy appears to be a combination of internal models (Blakemore & Sirigu, 2003; Kawato et al., 2003). These internal representations are used to 1) monitor intentions and plans and 2) verify if the motor action matches their intended goal (Caeyenberghs, Wilson, van Roon, Swinnen, & Smits-Engelsman, 2009). The more adequate the predictions are, which increase with age, the better the performance of the task (van Roon, Caeyenberghs, Swinnen, & Smits-Engelsman, 2008).

A possible way to evaluate eye-hand coordination is a visuo-manual tracking task in which a moving target is tracked by a cursor manipulated with other equipment (stylus, computer mouse or joy stick). Three phases in the development of tracking control are suggested (van Roon et al., 2008). First, children learn to stay with the cursor on top of the target. In the second phase, they learn the ability to anticipate on the target's motion, which makes it possible to track the target at higher velocities. The last phase is characterized by learning to rely less on visual feedback, which results in making fewer errors and the ability to track a moving target at higher velocities. Feedback and feedforward strategies are used to prevent and correct errors when tracking a target that follows a predictable trajectory at lower velocities. However, feedforward control is necessary when the target moves faster because the use of feedback becomes more difficult due to the visual-motor delay (Wolpert & Miall, 1996).

Evidence from previous studies using a visuo-manual tracking task (Caeyenberghs, van Roon, et al., 2009; Ferguson, Duysens, & Smits-Engelsman, 2015; van Roon et al., 2008; van Roon, Caeyenberghs, Swinnen, & Smits-Engelsman, 2010) suggests that children with Developmental Coordination Disorder (DCD), Acquired Brain Injury (ABI) or Learning Disorder (LD) are less competent in tracking a moving target in comparison with typically developing (TD) children from the same gender and age (Caeyenberghs, van Roon, et al., 2009; Ferguson et al., 2015; van Roon et al., 2010).

Despite the fact that the use of visuo-manual tracking tasks is very limited, these tasks could be an efficient and easily applicable way to measure eye-hand coordination in children. To use these tasks as an overall screening tool, more data is required to improve insights on eye-hand coordination in TD children from different age groups as well as children with a (developmental) disorder.

The aim of the present study was to examine the effect of age in TD children on eye-hand coordination, as well as the effect of gender in TD children from the same age, using a visuo-manual tracking task with accelerating target to examine if the children adapt to these changing velocities.

Firstly, we hypothesized that eye-hand coordination, measured by the performance of a visuo-manual tracking task with an accelerating target, improves with increasing age. In a previous study, the effect of age is investigated in TD children with a visuo-manual tracking task with an accelerating target dependent on the performance of the child. After having several children track a target at higher velocity, younger children show difficulties when trying to continuously track the target. The movements of tracking the target become smoother (i.e. fewer submovements) with increasing age. The amount of time they spend in the target is lower in younger age groups in comparison with older age groups (van Roon et al., 2008).

Secondly, we predicted that within the same age group, boys perform better than girls on the visuo-manual tracking task. Several studies have shown that boys perform better on the overall eye-hand coordination (e.g. throwing a ball) at all ages in comparison with girls (Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; Telford et al., 2013; Wicks, Telford, Cunningham, Semple, & Telford, 2015).

3 Methods

3.1 Participants

In this observational cross-sectional study, two primary schools and a youth organization in Flanders, Belgium were contacted for the recruitment of children from 6 to 12 years old. The predetermined amount of children to include for this study was 10 to 15 boys and 10 to 15 girls of each age from 6 to 12. If possible, a random selection was made from the children whose parents agreed to let them participate. The final number of participants of each age group depended on the number of informed consents obtained from the parents and on the available testing time (van Roon et al., 2008).

A questionnaire was drawn up by the researchers and communicated to the parents to determine if the child was diagnosed with any known visual disorder, mental retardation/intellectual disorder, hearing problem, metabolic disorder, neurological disorder, behavioral disorder, motor disability or developmental disorder, which were used as exclusion criteria.

Children were included if they 1) were between 6 and 12 years old, 2) had normal, or corrected to normal, vision, 3) spoke and understood Dutch, 4) went to a regular primary school and 5) had not failed a grade level at school.

Final sample size was 152 TD children (75 boys, 77 girls) (Figure 1). Additional information on these age groups is provided in Table 1. Handedness was determined by identifying the child's preferred writing hand by asking to write his/her name as recommended in the instructors' manual of the MABC-2 (Henderson S.E., 2007).

This study was approved by the local Ethics Committee of UHasselt (study CME2017/772 B9115201834829, January 9th 2018). The parents of all children gave written informed consent. All children gave their assent.

3.2 Procedure

Participants were asked to manually track a black circular target with a diameter of 1.30 centimeters. This target was presented on a computer screen (HP Compaq 8510p or HP Pavilion dv7) that was positioned vertically at approximately 40 centimeters from the participant's eyes. The target rotated clockwise for right-handed children, counterclockwise for left-handed children, along a circular path with a diameter of ten centimeters. The participants used a computer mouse as a cursor while they tried to track the target. They used their preferred hand to keep the cursor, represented by a small red dot (diameter = 0.25 centimeters), inside the black target. The digitizer was sampled at a frequency of 100 Hz and with an accuracy of 0.01 millimeter. The speed started at 30°/s (corresponding to 2.62 cm/s) and accelerated gradually to 60°/s (corresponding to 5.24 cm/s) (Ferguson et al., 2015; van Roon et al., 2008, 2010).

The participants received verbal and visual instructions prior to the task. They were instructed to keep the red dot on top of the black target as good as possible and were allowed to rest between the trials. This task typically lasted ten minutes.

All participants were allowed two practice trials, each 60 seconds, at a constant speed to get familiar with the task. This was followed by two trials of 60 seconds each where the target accelerated from 30°/s to 60°/s. Only the data of the first trial with the accelerating target was used in the statistical analysis.

Measurements of tracking performance reflected on the ability of the participant to keep the cursor within the target, even when the target accelerated. The primary outcome measures were defined based on previous studies (Caeyenberghs, van Roon, et al., 2009; Ferguson et al., 2015; van Roon et al., 2008, 2010). The first outcome measure was the mean distance between the center of the target and the center of the cursor to reflect the positional error, an outcome for the accuracy of the performance. The standard deviation of the distance between the centers represented the stability of the performance. The third outcome measure was the time in the target because this single unequivocal measure of performance was directly related to the ultimate aim of the tracking task.

3.3 Data analysis

The software JMP® Pro, Version 13.2.0 (SAS Institute Inc., Cary, NC, 1989-2007) was used to analyze the data.

Measures of performance included the mean and standard deviation of the distance between the center of the target and the center of the cursor and the time that the cursor spent in the target during one trial. These outcomes reflected the ability of the participant to successfully keep the cursor in the target, even when the target accelerated.

Because of the accelerating target, the difference between the first ten seconds and last ten seconds of one trial was calculated and used in the data analysis. This was a better representation of the performance, considering the acceleration, in comparison with the use of the mean of the whole trial.

The data analysis consisted a two-way ANOVA (Analysis of Variance) because of two categorical covariates (age groups and gender) and continue responses (mean and standard deviation of the distance between the centers of the cursor and the target and time in target). The effect of the between-groups factor age (to compare the means between the six different age groups) and the effect of the within-group factor gender (to evaluate the difference in one age group) were analyzed. To assess the equality of variances between the age groups, Levene's test was used. A normal distribution (tested with the Shapiro-Wilk W test), homoscedasticity and independence in all levels were evaluated before the statistical analysis. If one of these conditions wasn't fulfilled, non-parametric tests (Wilcoxon/Kruskall-Wallis) were performed. The Tukey all-pairs method as a post-hoc test was used in case of parametric tests, and in case of non-parametric tests, the Steel-Dwass all-pairs method. An alpha level of 0.05 was applied for all statistical tests.

4 Results

4.1 Distance between the center of the target and the center of the cursor

4.1.1 Mean

The mean distance between the center of the target and the center of the cursor decreased with age for the first and last ten seconds of one trial ($p < 0.01$) (Tables 2 and 3; Figure 2). No significant difference was found between the ages 6-7, 6-8, 8-9, 9-10, 9-11 and 10-11 for both the first and last ten seconds, and also between 7-8 for the last ten seconds (Tables 4 and 5). A positive correlation was found between the first and last ten seconds ($r = 0.74$; $p < 0.01$).

For the difference between the first and the last ten seconds of one trial, the mean distance decreased significantly in children when the difference between the age groups was three years or more, except between the ages 6-9 and 7-11 (Table 6; Figure 2).

The effect of gender failed to reach significance across all participants, as well as in each age group separately for the first ten seconds, last ten seconds and difference between the first and last ten seconds (respectively moment 1, 2 and 3). Only in the last ten seconds, girls of 7 years old performed significantly better than boys of the same age ($p = 0.03$) (Tables 13 and 14).

Levene's test showed a significant decrease of variances between the age groups for moment 1 ($F(5,146) = 7.46$; $p < 0.01$), moment 2 ($F(5,146) = 8.70$; $p < 0.01$) and moment 3 ($F(5,146) = 7.12$, $p < 0.01$) (Table 15; Figure 5).

4.1.2 Standard deviation

For the first and the last ten seconds of one trial, the standard deviation of the distance between the centers of the target and cursor decreased with age ($p < 0.01$) (Tables 2 and 3; Figure 3). The difference between the consecutive ages failed to reach significance, as well as between 6-8 and 9-11 (Tables 7 and 8). The correlation between the first and last ten seconds was found to be positive ($r = 0.63$; $p < 0.01$).

There was no significant age-related effect for difference between the first and last ten seconds of one trial ($p = 0.05$) (Table 3).

No significant effect of gender was found across all participants, as well as in each age group separately for the three moments. However, two exceptions were found: 1) boys of 10 years old performed significantly better than girls from the same age during the first ten seconds ($p = 0.02$) and 2) girls of 7 years old performed better during the last ten seconds ($p = 0.01$) (Tables 13 and 14).

A significant difference in the equality of variances was found between the age groups for moment 1 ($F(5,146) = 11.07$; $p < 0.01$), moment 2 ($F(5,146) = 7.74$; $p < 0.01$) and moment 3 ($F(5,146) = 7.19$, $p < 0.01$) and showed a decrease of the variances (Table 15; Figure 6).

4.2 Time in target

For the first ten seconds, the amount of time the cursor was in the target increased with age ($p < 0.01$) (Tables 2 and 3; Figure 4). Analyses of the main effect of age revealed that there was an overall significant difference between the age groups, except for the difference between age 6-7, 8-9, 9-10, 9-11 and 10-11 (Table 10).

The trend of the first ten seconds continued in the last ten seconds (Tables 2 and 3; Figure 4). The difference between age 6-7, 8-9, 9-10, 9-11 and 10-11 remained not significant, as well as for the difference between 6-8 and 7-8 (Table 11). A positive correlation was found between the first and last ten seconds ($r = 0.77$; $p < 0.01$).

The results of the ANOVA showed no significant interaction-effect between age and gender in the difference between the first and last ten seconds ($p = 0.78$) and no significant effect for age separately (Table 3). The difference between the first and last ten seconds for duration spent at the target remained approximately constant between the age groups (Tables 2 and 3; Figure 4).

The effect of gender for each age group failed to reach significance during the three moments (Tables 13 and 14).

The results of Levene's test showed a significant decrease in variances between the age groups for moment 1 ($F(5,146) = 2.79$; $p = .02$) and moment 2 ($F(5,146) = 2.34$; $p = 0.04$), contrary to moment 3 where the variances remained equal ($F(5,146) = 0.84$; $p = 0.53$) (Table 15; Figure 7).

5 Discussion

The aim of the present study was to examine the effect of age in typically developing (TD) children on eye-hand coordination, as well as the effect of gender in TD children from the same age using a visuo-manual tracking task with accelerating target. We hypothesized that TD children (1) improve their performance of tracking the target with increasing age, reflecting in a smaller mean distance and standard deviation of the distance between the center of the target and the center of the cursor and a longer time in target and (2) when examined in each age group, boys perform better on the visuo-manual tracking task than girls.

The main finding was that the overall performance of the children improved with age. Older children had a smaller mean distance and standard deviation of the distance between the centers of the target and the cursor and a longer time spent in the target in comparison with younger children. However, no differences were found between boys and girls for any age group.

Several factors might explain the age-related differences in task performance. The first and, according to our view, most important cause is the difficulty with anticipating the target's movement (predictive or prospective control). In visual tracking, as well as in manual tracking, the creation of a prospective model is important to adequately predict the movement of the target (van Roon et al., 2008). This relies on information from the preceding storage of the target's movement.

The first step in the process of the creation of this internal model is the construction of an accurate representation of the target position and movement, which can be used to successfully track the moving target. Second step is the ability to constantly update this model to predict the smooth pursuit of the moving target (Ferguson et al., 2015).

An internal positive feedback loop is assumed to be the basis for the memory of the target's motion, which contain a predictive estimation of the required velocity (Barnes, 2008; Desmurget & Grafton, 2000). The participants were given two practice trials, each of 60 seconds, which allowed them to develop a predictive internal model of the target's motion.

The cerebellum plays an important role in the construction of predictive internal models essential for 1) predicting the sensory consequences of movements, 2) the coordination between eye and hand movements and 3) online corrections of the movements (Kawato et al., 2003; Miall, Reckess, & Imamizu, 2001; Tseng, Diedrichsen, Krakauer, Shadmehr, & Bastian, 2007; Wolpert, Miall, & Kawato, 1998).

Several studies show that cerebellar volume increases with age and reaches its mature volume at around 12 years for girls and 16 years for boys (Sussman, Leung, Chakravarty, Lerch, & Taylor, 2016; Tiemeier et al., 2010; Wu, Chen, & Shen, 2011). This suggests that the older age groups can rely more on internal models in comparison with the younger age groups. The gradual replacement of the feedback-based strategy by feedforward processes are favorable for tracking high speed targets, because the use of feedback is more difficult when the target is moving at higher velocities (van Roon et al., 2008, 2010).

A second possible cause is the information processing speed, which increases with age. Older children have a greater ability to quickly process information necessary to perform a complex motor task. For example, older children can use online feedback on the position and velocity of the target longer when the target moves at higher velocities compared to younger children (Bourgeois & Hay, 2003).

A third factor that might have played a role in the differences between age groups is the decrease in variability of motor patterns with age. The development of coordination is characterized by a more consistent interjoint coordination and a decrease in trunk displacement and variability. From the age between 8 and 10, children have a variability in movement kinematics similar to adults (Schneiberg, Sveistrup, McFadyen, McKinley, & Levin, 2002). This also results in hand trajectories becoming smoother and less variable, which reflects in older children making fast adjustments in movement velocity (van Roon et al., 2008).

A final potential explanation is the development of the visual pursuit which improves with age. One study found that the smooth pursuit eye movements for tracking a moving target improves until the age of 15, but no older children were included (Ross, Radant, & Hommer, 1993). Another study which investigated the developmental differences in smooth pursuit eye movements found a better eye tracking performance from the late adolescent group (17-18 years) in comparison with the preadolescent group (11-12 years). This indicates an adult level of performance of the oculomotor system from the late adolescence (17-18 years), but that it is still developing and not working optimally during preadolescence (Katsanis, Iacono, & Harris, 1998). When an improvement in visual tracking is determined, an improvement in manual tracking is also expected since these competences are closely related in a visuo-manual tracking task (van Roon et al., 2008).

The previous explanations can also be related to a declaration for the wide-spread variances in performance of the younger age groups in comparison with the older age groups, changing at the age of 9. Another possible way to interpret the wide-spread variance, is the impact of one year in a 6-year-old child compared to one year of an 11-year-old. The children were classified by age, but difference can be considered between children born in January or December of the same year, for example. This one year difference is of a larger percentage in the lives of children of 6 years old compared to children of 11 years old.

Another important factor is that the development of the process towards laterality, also known as lateralization, increases with age. Lateralization is the development of experiencing dominance of one body side over the other. In the first year of primary school, children develop skills such as writing with their preferred hand. At this age, the hand function of both hands is still inconsistent. Between 7 and 9 years old, the hand function becomes more fluent and at the age of 9 it reaches its maturity. This could clarify the persistent stabilization of the variance and the results of the outcome measures from the age of 9 (van Grunsven, Njiokiktjien, Vuylsteke-Wauters, & Vranken, 2009). Younger children from the same age differ more in learning capabilities in comparison with older children, which lead to more variability in the younger children.

For a better representation of the performance, considering the acceleration of the target, the focus of the interpretation of the results was the difference between the first and last ten seconds instead of a total time average. After observing these results of the mean distance between the center of the target and the center of the cursor, a significant difference could only be seen between the age groups differing three or more years from each other, except for the age groups between 6-9 and 7-11. For the standard deviation of the distance and time in target, no significant differences were found between age groups for the difference between the first and last ten seconds. A possible explanation for the difficulty in reaching significance level for the difference between the first and last ten seconds is the same decline of performance between the children. The results of the children for the first ten seconds improved with age, as well as for the last ten seconds. Considering the positive correlation, the degree of improvement for the first and last ten seconds separately was comparable, which could explain the equality in difference between the first and last ten seconds.

No significant differences in performance were found in children with consecutive ages. This could be explained by the variances within the younger age groups. Their results had a wide-spread variance, which could cause an overlap between the high scores of one age group and the low scores of the consecutive age group. On the other hand, little variance was noticed within the results of the older age groups. In this case, the mean of the results of the age groups were closer which could explain the difficulty of reaching a significant difference.

There were no significant differences found in the performance of the tracking task between boys and girls across all participants and in any age group. A few exceptions were found but these were considered to be merely a coincidence because of the small amount (three out of 63 measures) (Table 14) and no similarities with the literature. These overall results reject our hypothesis, in which we hypothesized that boys would perform better than girls. A possible explanation for the better performance in eye-hand coordination tasks of boys compared to girls, is that boys perform better in tasks that include strength and/or endurance. These skills are not required to perform the visuo-manual tracking task. However, the results of the present study correspond to the results of studies in which they investigated the effect of gender and age in a non-digitalized pursuit rotor task (Thomas & French, 1985).

After observing the tasks, we concluded that there were no differences between the age groups nor between boys and girls regarding concentration, attention or motivation. For additional information, the computer use of the children was questioned. No differences were determined between boys and girls in the use of a tablet or computer. In general, present children played more games on tablets than on computers. This could be reflected in the way they grasped and manipulated the computer mouse. The use of a computer mouse could be considered as a limitation of the current study. Reflecting on the common use of a tablet in children, it could be interesting for further research to examine eye-hand coordination with a visuo-manual tracking task on a tablet.

One of the strengths of the present study is the large sample size compared with previous studies using the visuo-manual tracking task (Caeyenberghs, van Roon, et al., 2009; Ferguson et al., 2015; van Roon et al., 2010). We attempted to limit the effect of a learning disorder on the results by recruiting children of regular primary schools and excluding children who failed a grade level at school.

Our study differs from the one of van Roon et al. (van Roon et al., 2008) in the fact that the acceleration of the target did not depend on the performance of the child. In this study, the speed of the target gradually increased, which gave every child of each age the possibility to track the target in every velocity between 30°/s to 60°/s. We determined that it was a limitation to make the acceleration dependent on the performance of the child. Possibly, the child could track the target at higher velocities, but never had the opportunity to prove this because the performance of tracking a slow-moving target was not good enough to reach higher velocities.

A recommendation for further research is a larger sample size when examining the effect of gender. In our study, the number of boys and girls separately for each age group was rather small. This could be a possible cause for the lack of significant differences between boys and girls.

This study contributed to the requirement of collecting data of typically developing children to provide more reliable bases for comparison with children with a (developmental) disorder. The use of the visuo-manual tracking task as an overall screening tool could lead to a more accurate and faster diagnosis and treatment in children with a (developmental) disorder (Davol & Breakell, 1968).

6 Conclusion

The results of the current study showed that the overall performance of the visuo-manual tracking task examined in TD children improved with age. Younger children had more difficulties with anticipating the target's motion, especially at higher velocities, compared with older children. These findings were an indication for the continued improvement of feedforward control during childhood. Furthermore, no general differences were found in the performance between boys and girls for any age group. The results of this study with TD children could be used to provide more reliable bases as a comparison for children with a (developmental) disorder. The use of the visuo-manual tracking task could lead to a more accurate and faster diagnosis and treatment, as eye-hand coordination is of great importance to anticipate in many activities of daily life.

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8 Appendix

Table 1: Descriptive characteristics of the participants

Age Group (years)	**Total (N)**	**Female (N)**	**Male (N)**	**Age (years;months)**	
				M	SD
6	26	13	13	6;7	0;3
7	28	14	14	7;5	0;4
8	29	14	15	8;6	0;4
9	22	12	10	9;6	0;3
10	25	12	13	10;5	0;3
11	22	12	10	11;6	0;3

N = amount; M = Mean; SD = Standard Deviation

Table 2: Means and standard deviations of the dependent variables by age

Age	Mean distance target-cursor (cm)						SD distance target-cursor (cm)						Time in target (%)					
	First 10s		Last 10s		Difference last-first 10s		First 10s		Last 10s		Difference last-first 10s		First 10s		Last 10s		Difference last-first 10s	
	M	*SD*	M	*SD*	M	*SD*	M	*SD*	M	*SD*	M	*SD*	M	*SD*	M	*SD*	M	*SD*
6	1.12	*1.20*	1.77	*1.17*	0.65	*1.21*	0.83	*1.07*	1.14	*0.79*	0.31	*1.14*	51.85	*20.65*	19.52	*10.34*	-0.33	*0.17*
7	0.98	*0.86*	1.77	*1.12*	0.79	*1.04*	0.70	*0.75*	1.21	*0.89*	0.51	*1.02*	48.78	*21.69*	19.98	*14.58*	-0.29	*0.16*
8	0.59	*0.19*	1.22	*0.73*	0.63	*0.66*	0.38	*0.21*	0.82	*0.69*	0.44	*0.57*	67.20	*16.49*	33.27	*18.61*	-0.36	*0.15*
9	0.45	*0.12*	0.86	*0.41*	0.41	*0.36*	0.25	*0.10*	0.57	*0.47*	0.32	*0.48*	78.37	*11.03*	44.65	*14.09*	-0.34	*0.14*
10	0.44	*0.11*	0.70	*0.19*	0.26	*0.17*	0.25	*0.09*	0.42	*0.17*	0.17	*0.14*	81.12	*13.90*	51.66	*17.08*	-0.29	*0.14*
11	0.48	*0.34*	0.75	*0.35*	0.27	*0.19*	0.31	*0.35*	0.47	*0.36*	0.16	*0.20*	84.30	*15.81*	52.50	*17.90*	-0.32	*0.13*

M = Mean; SD = Standard Deviation; s = seconds; cm = centimeter

Table 3: Effect of age across all participants

	Mean distance target-cursor			SD distance target-cursor			Time in target		
	First 10s	Last 10s	Difference last-first 10s	First 10s	Last 10s	Difference last-first 10s	First 10s	Last 10s	Difference last-first 10s
	p	p	p	p	p	p	p	p	p
Age	**<.01***	**<.01***	**<0.01***	**<.01***	**<.01***	0.05	**<.01***	**<.01***	0.55

SD = Standard Deviation; s = seconds; p = p-value; * = significant

Table 4: Results mean distance by age group – first 10 seconds

Age group 1	Age group 2	MD	SED	p
6	7	1.45	4.29	1.00
6	8	-10.54	4.33	0.14
6	9	-17.41	4.06	**<.01***
6	10	-19.26	4.16	**<.01***
6	11	-18.17	4.06	**<.01***
7	8	-13.23	4.40	**0.03***
7	9	-20.09	4.15	**<.01***
7	10	-21.01	4.25	**<.01***
7	11	-19.36	4.15	**<.01***
8	9	-10.67	4.20	0.11
8	10	-14.23	4.29	**0.01***
8	11	-15.47	4.20	**<.01***
9	10	-2.35	4.01	0.99
9	11	-6.32	3.87	0.58
10	11	-3.03	4.01	0.97

MD = Mean Difference; SED = Standard Error Difference; p = p-value; * = significant

Table 5: Results mean distance by age group – last 10 seconds

Age group 1	Age group 2	MD	SED	p
6	7	0.04	4.29	1.00
6	8	-11.05	4.33	0.11
6	9	-16.91	4.06	**<.01***
6	10	-21.77	4.16	**<.01***
6	11	-19.09	4.06	**<.01***
7	8	-10.85	4.40	0.13
7	9	-14.57	4.15	**0.01***
7	10	-19.88	4.25	**<.01***
7	11	-17.25	4.15	**<.01***
8	9	-10.35	4.20	0.14
8	10	-15.79	4.29	**<.01***
8	11	-13.79	4.20	**0.01***
9	10	-4.40	4.01	0.88
9	11	-5.23	3.87	0.76
10	11	-1.15	4.01	1.00

MD = Mean Difference; SED = Standard Error Difference; p = p-value; * = significant

Table 6: Results mean distance by age group – difference between first and last 10 seconds

Age group 1	Age group 2	MD	SED	p
6	7	0.11	4.23	1.00
6	8	-4.63	4.33	0.89
6	9	-8.35	4.06	0.31
6	10	-13.14	4.16	**0.02***
6	11	-12.29	4.06	**0.03***
7	8	-4.81	4.40	0.88
7	9	-7.10	4.15	0.53
7	10	-12.61	4.25	**0.04***
7	11	-11.73	4.15	0.05
8	9	-5.64	4.20	0.76
8	10	-11.62	4.29	0.07
8	11	-12.35	4.20	**0.04***
9	10	-5.34	4.01	0.77
9	11	-6.05	3.87	0.62
10	11	0.04	4.01	1.00

MD = Mean Difference; SED = Standard Error Difference; p = p-value; * = significant

Table 7: Results standard deviation of the distance by age group – first 10 seconds

Age group 1	Age group 2	MD	SED	p
6	7	1.15	4.29	1.00
6	8	-7.84	4.33	0.46
6	9	-17.41	4.06	**<.01***
6	10	-17.22	4.16	**<.01***
6	11	-16.74	4.06	**<.01***
7	8	-9.23	4.40	0.29
7	9	-18.39	4.15	**<.01***
7	10	-18.44	4.25	**<.01***
7	11	-17.17	4.15	**<.01***
8	9	-11.71	4.20	0.06
8	10	-13.11	4.29	**0.03***
8	11	-14.43	4.20	**0.01***
9	10	-0.56	4.01	1.00
9	11	-4.68	3.87	0.83
10	11	-4.06	4.01	0.91

MD = Mean Difference; SED = Standard Error Difference; p = p-value; * = significant

Table 8: Results standard deviation of the distance by age group – last 10 seconds

Age group 1	Age group 2	MD	SED	p
6	7	0.33	4.29	1.00
6	8	-7.91	4.33	0.45
6	9	-13.64	4.06	**0.01***
6	10	-18.40	4.16	**<.01***
6	11	-17.08	4.06	**<.01***
7	8	-8.95	4.40	0.32
7	9	-14.89	4.15	**<.01***
7	10	-19.42	4.25	**<.01***
7	11	-17.98	4.15	**<.01***
8	9	-9.47	4.20	0.21
8	10	-14.45	4.29	**0.01***
8	11	-14.03	4.20	**<.01***
9	10	-2.18	4.01	0.99
9	11	-4.05	3.87	0.90
10	11	-1.84	4.01	1.00

MD = Mean Difference; SED = Standard Error Difference; p = p-value; * = significant

Table 9: Results standard deviation of the distance by age group - difference between first and last 10 seconds

Age group 1	Age group 2	MD	SED	p
6	7	1.82	4.29	0.10
6	8	-0.69	4.33	1.00
6	9	-3.15	4.06	0.97
6	10	-6.32	4.16	0.65
6	11	-6.59	4.06	0.58
7	8	-3.62	4.40	0.96
7	9	-6.62	4.15	0.60
7	10	-10.34	4.25	0.15
7	11	-9.54	4.15	0.20
8	9	-4.84	4.20	0.86
8	10	-8.19	4.29	0.40
8	11	-9.87	4.20	0.17
9	10	-2.09	4.01	1.00
9	11	-3.32	3.87	0.96
10	11	-3.29	4.01	0.96

MD = Mean Difference; SED = Standard Error Difference; p = p-value; * = significant

Table 10: Results time in target by age group – first 10 seconds

Age group 1	Age group 2	MD	SED	p
6	7	-2.41	4.29	0.99
6	8	13.71	4.33	**0.02***
6	9	17.87	4.06	**<.01***
6	10	19.58	4.16	**<.01***
6	11	19.18	4.06	**<.01***
7	8	15.72	4.40	**<.01***
7	9	19.40	4.15	**<.01***
7	10	20.63	4.25	**<.01***
7	11	19.97	4.15	**<.01***
8	9	9.87	4.20	0.17
8	10	13.30	4.29	**0.02***
8	11	16.35	4.20	**<.01***
9	10	4.49	4.01	0.87
9	11	8.73	3.87	0.21
10	11	4.10	4.01	0.91

MD = Mean Difference; SED = Standard Error Difference; p = p-value; * = significant

Table 11: Results time in target by age group – last 10 seconds

Age group 1	Age group 2	MD	SED	p
6	7	-0.89	4.28	1.00
6	8	12.00	4.33	0.06
6	9	19.68	4.06	**<.01***
6	10	22.24	4.16	**<.01***
6	11	21.23	4.06	**<.01***
7	8	11.16	4.40	0.11
7	9	19.40	4.15	**<.01***
7	10	22.11	4.25	**<.01***
7	11	20.62	4.15	**<.01***
8	9	9.51	4.20	0.21
8	10	14.38	4.29	**0.01***
8	11	14.39	4.20	**0.01***
9	10	6.07	4.01	0.66
9	11	5.77	3.87	0.67
10	11	0.21	4.01	1.00

MD = Mean Difference; SED = Standard Error Difference; p = p-value; * = significant

Table 12: Results time in target by age group – difference between first and last 10 seconds

Age group 1	Age group 2	MD	SED	p
6	7	0.04	0.04	0.96
6	8	0.03	0.04	0.96
6	9	0.01	0.04	1.00
6	10	0.03	0.04	0.98
6	11	0.01	0.04	1.00
7	8	0.07	0.04	0.52
7	9	0.05	0.04	0.87
7	10	0.01	0.04	1.00
7	11	0.03	0.04	0.99
8	9	0.02	0.04	1.00
8	10	0.06	0.04	0.65
8	11	0.04	0.04	0.92
9	10	0.04	0.05	0.93
9	11	0.02	0.05	1.00
10	11	0.02	0.04	1.00

MD = Mean Difference; SED = Standard Error Difference; p = p-value; * = significant

Table 13: Means and standard deviations of the dependent variables by gender

Age	Gender	Mean distance target-cursor (cm)						SD distance target-cursor (cm)						Time in target (%)					
		First 10s		Last 10s		Difference last-first 10s		First 10s		Last 10s		Difference last-first 10s		First 10s		Last 10s		Difference last-first 10s	
		Me	*SD*	Me	*SD*	Me	*SD*	Me	*SD*	Me	*SD*	Me	*SD*	Me	*SD*	Me	*SD*	Me	*SD*
6	M	1.02	*0.80*	2.11	*1.50*	1.09	*0.88*	0.78	*0.92*	1.45	*0.93*	0.67	*1.19*	0.47	*0.22*	0.18	*0.10*	-0.29	*0.20*
	F	1.21	*1.53*	1.42	*0.66*	0.21	*1.28*	0.87	*1.24*	0.83	*0.47*	-0.04	*1.02*	0.57	*0.19*	0.21	*0.11*	-0.36	*0.15*
7	M	1.15	*1.13*	2.33	*1.35*	1.17	*1.29*	0.78	*0.87*	1.67	*1.03*	0.89	*1.11*	0.43	*0.23*	0.18	*0.18*	-0.25	*0.18*
	F	0.80	*0.45*	1.21	*0.35*	0.40	*0.52*	0.62	*0.63*	0.75	*0.36*	0.13	*0.78*	0.55	*0.19*	0.22	*0.10*	-0.33	*0.13*
8	M	0.58	*0.19*	1.19	*0.75*	0.61	*0.64*	0.40	*0.24*	0.81	*0.63*	0.41	*0.42*	0.68	*0.18*	0.37	*0.22*	-0.35	*0.16*
	F	0.60	*0.20*	1.25	*0.75*	0.66	*0.71*	0.37	*0.17*	0.83	*0.76*	0.46	*0.70*	0.66	*0.16*	0.90	*0.15*	-0.37	*0.15*
9	M	0.49	*0.10*	0.80	*0.35*	0.36	*0.35*	0.24	*0.06*	0.54	*0.51*	0.31	*0.52*	0.77	*0.12*	0.44	*0.14*	-0.33	*0.18*
	F	0.46	*0.15*	0.92	*0.46*	0.46	*0.38*	0.26	*0.12*	0.59	*0.47*	0.34	*0.48*	0.80	*0.11*	0.45	*0.15*	-0.35	*0.10*
10	M	0.40	*0.08*	0.65	*0.15*	0.25	*0.14*	0.21	*0.06*	0.39	*0.13*	0.18	*0.10*	0.86	*0.10*	0.56	*0.15*	-0.31	*0.17*
	F	0.48	*0.12*	0.76	*0.22*	0.28	*0.20*	0.29	*0.11*	0.45	*0.20*	0.16	*0.18*	0.76	*0.16*	0.47	*0.19*	-0.28	*0.12*
11	M	0.49	*0.32*	0.73	*0.34*	0.25	*0.20*	0.30	*0.31*	0.42	*0.26*	0.12	*0.18*	0.82	*0.20*	0.55	*0.22*	-0.27	*0.14*
	F	0.49	*0.36*	0.78	*0.37*	0.29	*0.20*	0.32	*0.40*	0.52	*0.43*	0.20	*0.22*	0.86	*0.12*	0.50	*0.14*	-0.36	*0.12*

M = Male; F = Female; Me = Means; SD = Standard Deviation; s = seconds; cm = centimeter

Table 14: Effect of gender on each age group

Age	Mean distance target-cursor			SD distance target-cursor			Time in target		
	First 10s	Last 10s	Difference last-first 10s	First 10s	Last 10s	Difference last-first 10s	First 10s	Last 10s	Difference last-first 10s
	p	p	p	p	p	p	p	p	p
All	0.84	0.97	0.79	0.61	0.40	0.15	0.79	0.79	0.28
6	0.28	0.15	0.10	0.88	0.08	0.14	0.22	0.59	1.00
7	0.45	**0.03***	0.10	0.98	**0.01***	0.06	0.22	0.15	0.94
8	0.98	0.50	0.31	1.00	0.84	0.68	0.50	0.38	1.00
9	0.67	0.77	0.82	0.82	0.53	0.82	0.58	0.92	1.00
10	0.05	0.20	0.64	**0.02***	0.57	0.57	0.09	0.26	1.00
11	0.82	0.28	0.31	0.97	0.37	0.49	0.77	0.41	0.96

SD = Standard Deviation; p = p-value; s = seconds; * = significant

Table 15: Variances by age

	Mean distance target-cursor						**SD distance target-cursor**						**Time in target**					
	First 10s		Last 10s		Difference last-first 10s		First 10s		Last 10s		Difference last-first 10s		First 10s		Last 10s		Difference last-first 10s	
	F	p	F	p	F	p	F	p	F	p	F	p	F	p	F	p	F	p
Age	7.46	**<.01***	8.70	**<.01***	7.12	**<.01***	11.07	**<.01***	7.74	**<.01***	7.19	**<.01***	2.79	**0.02***	2.34	**0.04***	0.84	0.53

SD = Standard Deviation; F = F-ratio; p = p-value; s = seconds; * = significant

Place recruitment

- Limburg: two primary schools and one youth organisation

Total

- 162 children
  - Primary school Zonhoven: 6 y/o: 22 (13 ♂, 9 ♀), 7 y/o: 28 (13 ♂, 15 ♀), 8 y/o: 29 (15 ♂, 14 ♀), 9 y/o: 22 (10 ♂, 12 ♀), 10 y/o: 18 (11 ♂, 7 ♀) en 11 y/o: 24 (11 ♂, 13 ♀)
  - Primary school Bilzen: 10 y/o: 9 (5 ♂, 4 ♀
  - Chiro Meeuwen-Gruitrode: 6 y/o: 6 (2 ♂, 4 ♀), 7 y/o: 2 (2 ♂), 8 y/o: 1 (1 ♀) and 10 y/o: 1 (1 ♀)

Exclusion

- 10 children
  - Criteria: visual disorder (n=1), behavioral disorder (n=3), failed a grade level at school (n=2) and incomplete informed consent (n=4)

Total included children

- 152 children
  - 6 y/o: 26 (13 ♂, 13 ♀)
  - 7 y/o: 28 (14 ♂, 14 ♀)
  - 8 y/o: 29 (15 ♂, 14 ♀)
  - 9 y/o: 22 (10 ♂, 12 ♀)
  - 10 y/o: 25 (13 ♂, 12 ♀)
  - 11 y/o: 22 (10 ♂, 12 ♀)

Figure 1: Flowchart recruitement

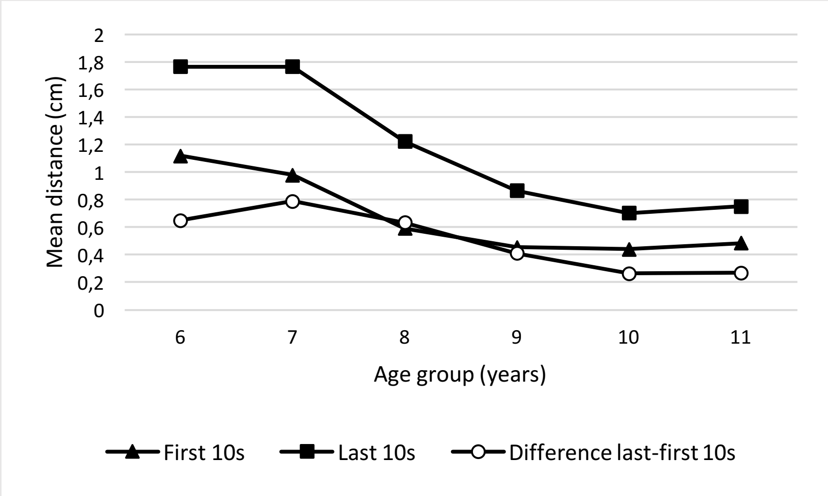

Figure 2: Mean distance by age

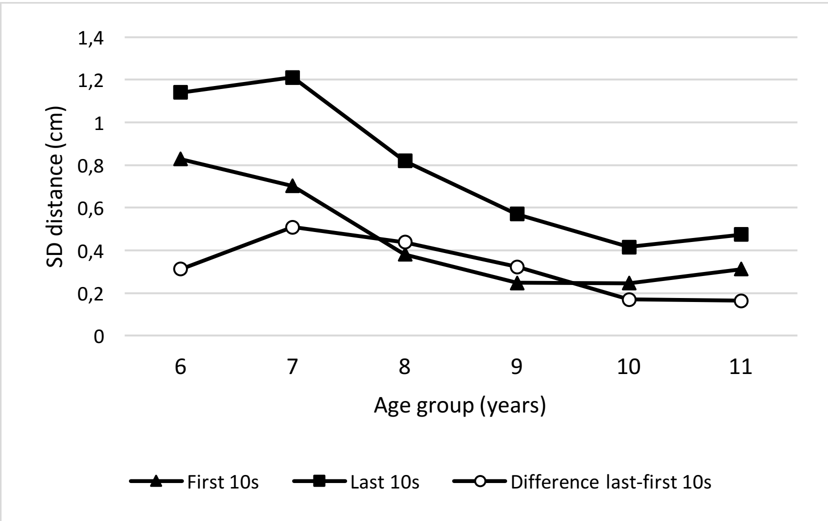

Figure 3: Standard deviations of the distance by age

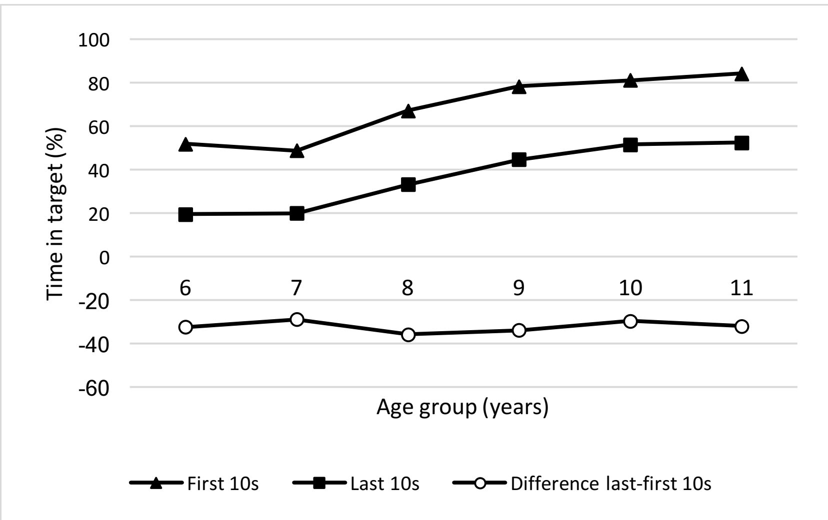

Figure 4: Time in target by age

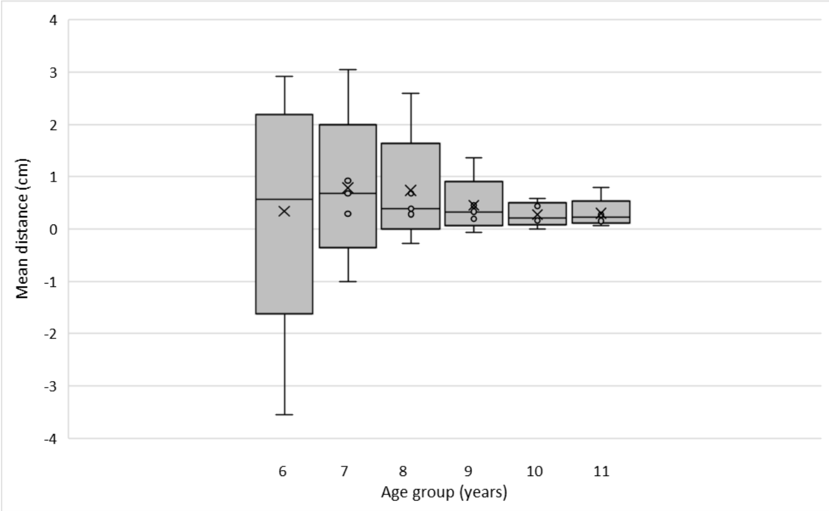

Figure 5: Boxplot: Mean distance – difference between first and last 10 seconds

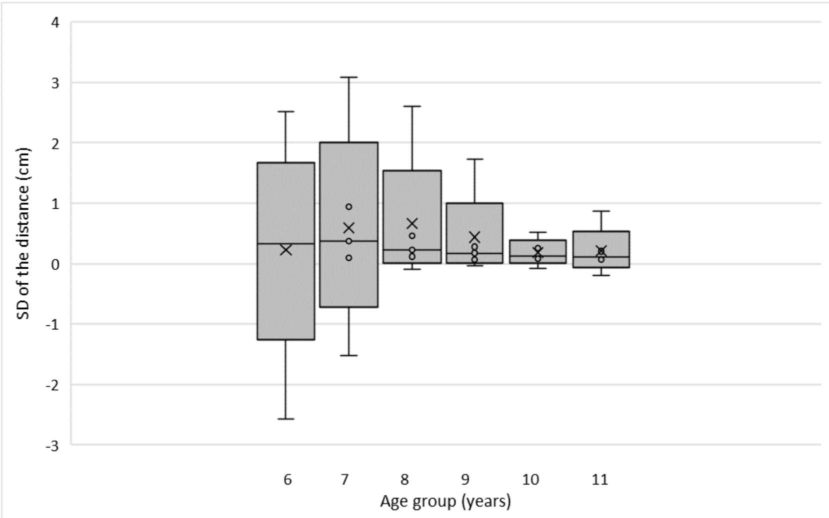

Figure 6: Boxplot: Standard deviation of the distance – difference between first and last 10 seconds

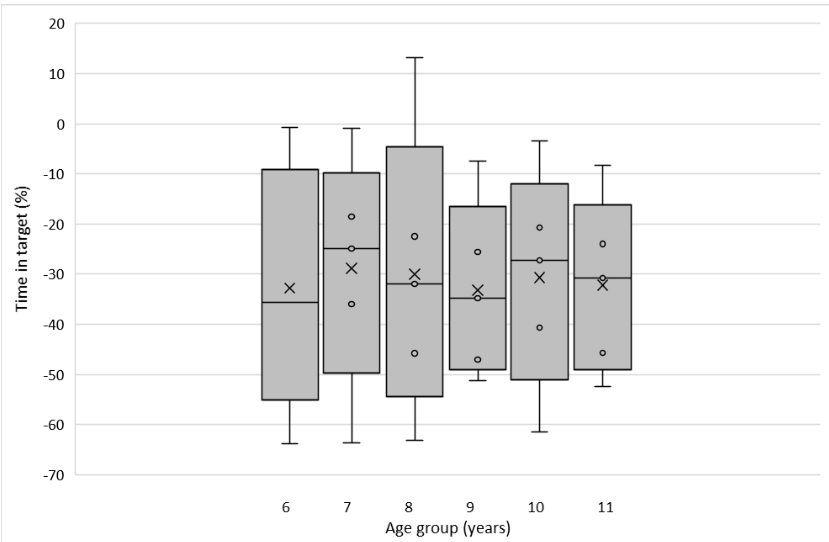

Figure 7: Boxplot: Time in target – difference between first and last 10 seconds

UHASSELT

VOORTGANGSFORMULIER WETENSCHAPPELIJKE STAGE DEEL 2

DATUM	INHOUD OVERLEG	HANDTEKENINGEN
05/ 07/ '18	samenkomst met mevr. Klingels, Lotte en Annemart. Bespreking samenwerking en studie protocols. Afspraken opstellen Ethische commissie	Promotor: Copromotor: Student(e): Student(e):
20/ 11/ '18	skypesessie proefversie van meetinstrument	Promotor: Copromotor: Student(e): Student(e):
07/ 02/ '18	afspraak met industrieel ingenieurs. uitleg meetinstrument	Promotor: Copromotor: Student(e): Student(e):
23/ 04/ '18	Bespreken meetresultaten en overleg statistiek.	Promotor: Copromotor: Student(e): Student(e):
4/ 05/ '18	Samenkomst met mevr. Klingels en Annemart. Bespreking data-analyse	Promotor: Copromotor: Student(e): Student(e):
15/ 05/ '18	Bespreking statistische analyse	Promotor: Copromotor: Student(e): Student(e):
23/05/ '18	Bespreking resultaten	Promotor: Copromotor: Student(e): Student(e):
		Promotor: Copromotor: Student(e): Student(e):
		Promotor: Copromotor: Student(e): Student(e):
		Promotor: Copromotor: Student(e): Student(e):