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Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

Auditory motor coupling and rhythm perception in children with Developmental Coordination Disorder compared to typically developing children: a case-controlled study

Janique Roufs
Annelise Vos

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. Eugene RAMECKERS

BEGELEIDER :
Mevrouw Mieke GOETSCHALCKX

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Content

Acknowledgement

We wish to extend our special thanks to several people for helping us finalize this project. The completion of this study could not have been possible without the help and expertise of our promotor Prof. Dr. Eugene Rameckers and our mentor dra. Mieke Goetschalckx. The guidance, patience and motivation of dra. Mieke Goetschalckx helped us through the research and writing of this thesis. We could not have imagined a better mentor for our master thesis.

A debt of gratitude is also owed to researchers Silke Velghe, Evi Verbecque and Charlotte Johnson for organizing a camp for children with Developmental Coordination Disorder and providing us with the chance to recruit more participants for our study. Furthermore, we would like to thank the University of Hasselt for providing us with the necessary materials and places to conduct this research. Finally, we are extremely grateful to all the children and parents who took the time to participate in our study. Without them, this study could not be possible.

Janique Roufs, Leon Biessenstraat 48, 6418TL Heerlen, 06/06/2022 J.R.

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Research context

It is widely known that children with Developmental Coordination Disorder (DCD) encounter problems with motor coordination, but the underlying reason is to date not fully understood. A possible hypothesis might be that difficulties with the internal modeling system cause these problems (Trainor, Chang, Cairney, & Li, 2018). This system is used to be able to adapt, plan or automatize movement, but to do so a decent (timing) prediction has to be made and a person must learn from previously made mistakes. The system consists of an inverse model, which forms a motor command based on the desired motor outcome, used in combination with a forward model, which predicts the desired motor outcome. If both models are used together, future predictions can be made resulting in rapid online motor control. In this model sensory and motor predictions simultaneously work together for sensorimotor synchronization. Auditory-motor coupling, or linking a sound to a movement, is part of this sensorimotor synchronization.

Literature describes motor deficits in DCD children, including problems with motor and sensorimotor timing (Lense, Ladányi, Rabinowitch, Trainor, & Gordon, 2021; Montes-Montes, Delgado-Lobete, & Rodríguez-Seoane, 2021). As proposed by Lense et al. (2021), poor timing, also seen as a poor internal modeling system, might explain the motor deficits in these children. Even though the sensory and motor system are inevitably connected, little research has been conducted to investigate auditory-motor coupling and rhythm perception in DCD. Research by Chang et al. (2021) found that children at risk for DCD have inferior auditory timing compared with typically developing children. This finding might support the hypothesis for motor deficits in DCD children, because without decent sensory perception, in this case, auditory perception, a decent motor performance could be lacking. Therefore, it is interesting to know whether inferior rhythm perception in DCD children impacts the lack of coordination in this child population.

The information of this research is of great importance for physiotherapists who rehabilitate children with DCD. Because of a gap in the literature about the link between auditory timing, motor timing and auditory-motor coupling, this research will try to provide answers to this question. With this information, researchers could build forward on providing answers to the impact of auditory-motor coupling on the coordination of DCD children. If positive results would be found in this study, rhythms could possibly be implemented in the rehabilitation of children with DCD for improving coordination.

This master thesis is situated within the framework of pediatric rehabilitation. The research is part of an ongoing doctoral research project of dra. Mieke Goetschalckx at the University of Hasselt, regarding the study with title: “Rhythmic interlimb coordination in children with Developmental coordination disorder compared to typically developing children: the effects of individual, task and environmental constraints”. As a consequence of being part of an ongoing research project, the protocol and study setup were already determined.

We provided 15% of the recruited participants. The remaining participants were recruited by other master students, dra. Mieke Goetschalckx and researchers Silke Velghe, Evi Verbecque and Charlotte Johnson, who organized a DCD-camp. Data acquisition was in collaboration with dra. Mieke Goetschalckx because she had access to the equipment and was trained to execute the tests on a standardized matter. Dra. Mieke Goetschalckx mainly took the gait tests, while we took the descriptive tests (movement Assessment Battery for Children version 2, go-no-go test, digit span forward and backward, rhythm perception tests and the anthropometric parameters of the participants). Because this research focused on a small part of the original protocol, only tests and data of use for this study were implemented. The data processing, as well as the academic writing process, was performed by ourselves. Annelise Vos mainly processed the data of the anthropometric characteristics, whereas Janique Roufs processed the data for the research questions. Dra. Mieke Goetschalckx and Prof. dr. Eugene Rameckers provided us with feedback to improve our master thesis.

Reference list research context

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1. Abstract

Background: Children with Developmental Coordination Disorder (DCD) encounter problems with fine and/or gross motor skills in daily living, affecting their participation in leisure activities. These problems might be due to difficulties with (timing) perception. Literature about rhythm perception and auditory-motor coupling in children is scarce.

Objectives: The purpose of this study is to investigate rhythm perception and auditory-motor coupling in typically developing (TD) and DCD children.

Participants: Twenty-five children (age 8 to 12y) were included in this study; 14 children were included in the TD group and 11 in the DCD group.

Measurements: The Montreal Battery of Evaluation of Musical Abilities (MBEMA), melody and rhythm subtests were used for measuring rhythm perception. Auditory-motor coupling was measured using tasks where participants walked to the beat of an isochronous and non-isochronous metronome. This was repeated in different tempi (+10% and -10% of comfortable walking pace).

Results: A significant group effect was found for rhythm perception (p=0.0301), this was influenced by age and following musical classes. Auditory-motor coupling ability in the comfortable walking pace condition showed a significant effect for group*(isochronous) metronome type (p=0.0158) and a significant between-group difference (p=0.0061) for synchronization variability. In the +10% condition, there was a trend that DCD children synchronize more variably (p=0.0624: non-isochronous; p=0.0552: isochronous). In the -10% condition, synchronization to the non-isochronous metronome condition was significantly different (p=0.0048) between DCD and TD children, but variability was not. Lastly, we found no significant correlation between rhythm perception and auditory-motor coupling for both metronomes in children with DCD.

Conclusion: Children with DCD have different rhythm perception abilities than TD controls. In comfortable walking pace DCD children synchronize worse and more variable on auditory-motor coupling tasks. Furthermore, there is no correlation between rhythm perception and auditory-motor coupling in DCD children.

Keywords: children, auditory-motor coupling, rhythm perception, Developmental Coordination Disorder, DCD, typically developing children, TD.

2. Introduction

Developmental Coordination Disorder (DCD) is a neurodevelopmental disorder characterized by impairments in motor performance. The disorder has a prevalence of 6% in children between the ages of 5 and 13. These children encounter multiple impairments that interfere with the child's daily living, including academic achievements and leisure participation (Zwicker, Missiuna, Harris, & Boyd, 2012) and these impairments cannot be explained by any neurological condition or intelligence score (American Psychiatric Association, 2013). Because of the interference with a child's daily living, physiotherapy is indicated to improve their functioning.

Auditory-motor coupling and rhythm perception are a part of our daily functioning, since children and adults tend to react to and produce music (Dalla Bella, 2018). Two studies proposed that if the perception of rhythms in DCD children is lacking, the sensorimotor synchronization or auditory-motor coupling might be poor and motor deficits could occur. Firstly, Trainor et al. (2018) proposed that DCD children might have auditory perceptual timing deficits, which leads to difficulties with the internal modeling system. This system makes it possible to predict future motor commands by the integration of sensorimotor feedback from previous movements. However, a decent (timing) perception is necessary to be able to plan or adapt movements. Secondly, a review by Lense et al. (2021) further describes that poor timing might explain the motor deficits that children with DCD encounter. It is interesting to know if by using rhythms or music in therapy, improvements in motor impairments of DCD children can be achieved by means of neuroplasticity and by improving (motor and/or sensorimotor) timing. Dalla Bella (2018) describes music which consists of rhythms, as a means to stimulate and induce brain plasticity, by recruiting a variety of brain structures.

DCD children encounter problems with fine and/or gross motor skills, but also with balance and motor learning (Lense et al., 2021). These difficulties might exist because of perceptual deficits, as forementioned above. Nonetheless, only one study has been conducted that relates to rhythm perception (Chang et al., 2021), which can be described as the ability to recognize and process a musical rhythm. This research reported an inferior rhythm perception in children with DCD, which was assessed by three perception tests regarding rhythm discrimination, duration discrimination and pitch discrimination. Therefore, the first aim of this study is to investigate the difference in rhythm perception between typically developing (TD) children and children with DCD by using a specific test battery, the Montreal Battery for Evaluation of Musical Abilities (MBEMA). We hypothesized that children with DCD encounter more difficulties with rhythm perception in comparison with TD children.

Auditory-motor coupling or rhythm synchronization is the integration of an auditory stimulus and a motor output, for example listening and dancing to the beat of music. A study by Rosenblum and Regev (2013) examined auditory-motor coupling in children with DCD compared with typically developing children by using an interactive metronome. They found a worse synchronization in DCD children, with a longer response time. Other studies report similar results, with DCD children performing lower and more variable on auditory-motor coupling tasks (Roche, Viswanathan, Clark, & Whitall, 2016; Whitall et al., 2008; Whitall et al., 2006). Our second aim of this study is to examine the difference in the ability and variability in auditory-motor coupling between TD and DCD children during a walking task. We hypothesized that DCD children will perform worse and more variable than TD children. Previous studies assessed auditory-motor coupling by using tapping tasks (Roche et al., 2016; Whitall et al., 2008) or as previously mentioned an interactive metronome (Rosenblum & Regev, 2013). This study will be the first to assess auditory-motor coupling of DCD children with a walking task. In our opinion walking tasks are more similar to everyday demands, therefore the results of this study might be of more clinical value.

Lastly, in literature, there is a lack of decent quality research providing information about the link between rhythm perception and auditory-motor coupling in children with DCD. Research by Puyjarinet, Bégel, Lopez, Dellacherie, and Dalla Bella (2017) examined this link in children and adults with Attention Deficit Hyperactivity Disorder (ADHD). Results showed higher motor variability in the ADHD group and poorer synchronization performance. This indicates that for a decent and accurate auditory-motor coupling, motor coordination, as well as rhythm perception, are important components. Because DCD has a high comorbidity with ADHD (Montes-Montes et al., 2021), we would like to examine the link between rhythm perception and auditory-motor coupling in DCD children. Therefore, the last aim of this study is to examine the correlation between rhythm perception and auditory-motor coupling in DCD children compared to TD children. For our last research question, we hypothesized that there is a link between the ability and variability of auditory-motor coupling and rhythm perception in children with DCD.

3. Method

3.1 Research design:

This case-controlled study aimed to compare auditory-motor synchronization between children with Developmental Coordination Disorder (DCD) and typically developing children (TD). Participants were divided into two groups according to (1) their DSM-V diagnosis, (2) results on the Movement Assessment Battery for Children version 2 (m-ABC-2), (3) results on a general health questionnaire and (4) the results on the Developmental Coordination Disorder Questionnaire (DCD-Q). Blinding of assessors and statistical analysts was difficult in this study since motor difficulties are easily recognized in children with (probable) DCD and detected in the scores on the m-ABC-2. Blinding of participants was unattained as well since most children and parents knew about their diagnosis.

3.2 Participants

Eleven children with DCD (mean age: 10.12 ± 1.2 years; 9 boys, 2 girls) and 14 typically developing children (mean age: 10.39 ± 1.2 years; 5 boys, 9 girls) participated in this study. The parents of all participants received and signed an informed consent form before testing.

3.2.1 Recruitment

In this study, children with Developmental Coordination Disorder (DCD) and typically developing children (TD) were included. Participants were recruited by contacting physical therapists, schools and sports facilities in the regions of Hasselt, Genk and Mol (Belgium). Physical therapists were asked to refer children with a DCD diagnosis, whereas schools were asked to refer children with and without a DCD diagnosis. All children who met the selection criteria and were interested to participate in this study were included.

For recruitment, we used mouth-to-mouth information and flyers that were hung up in schools and sports facilities. Besides, a DCD-camp organized by researchers Silke Velghe, Evi Verbecque, Charlotte Johnson and Mieke Goetschalckx yielded participants for the (probable) DCD subgroup. This camp took place in collaboration with Hasselt University.

3.2.2 Inclusion criteria

Inclusion criteria consist of subgroup-specific inclusion criteria and general inclusion criteria. General criteria are as followed: participants had to be (1) aged between 8 years and 12 years 11 months and 30 days, (2) have no history of medical conditions that affect their motor abilities, excluding DCD and (3) have sufficient knowledge of the Dutch language in order to understand spoken and read instructions.

(Probable) DCD-subgroup criteria consisted of (1) a diagnosis based on the DSM-V criteria for DCD and/or a total percentile score lower than or equal to percentile sixteen or a subdomain score lower than or equal to percentile five on the m-ABC-2 and (2) the motor impairments should negatively influence activities of daily life according to the DCD-Q. Motor impairments were considered to be a negative influence when scores were lower than or equal to 55 for children aged between 8 and 10 years old and scores lower than or equal to 57 for children aged between 10 and 15 years old. Lastly, (3) the onset of symptoms had to be during childhood. The general health questionnaire was used for checking whether this criterion was met. The TD-subgroup specific inclusion criterion was a total score on the m-ABC-2 higher than the 25th percentile.

3.2.3 Exclusion criteria

Children were excluded if they (1) did not meet the inclusion criteria, (2) had visual or hearing impairments or (3) had other musculoskeletal, neurological, cardiorespiratory, communication or intellectual impairments that affected their motor abilities. This was verified using a health questionnaire. The in- and exclusion criteria are found in table 1. Appendix 1 provides a visual representation of the selection procedure in a flowchart.

Table 1
Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Age: 8y to 12y 11m 30d	Visual or hearing impairments
TD: - Score mABC-2 25th percentile DCD: - Diagnosis based on the DSM-V criteria OR Total score m-ABC-2 PC≤16th OR Score ≥1 subdomain m-ABC-2 PC≤ 5th - Score ≤55 for children 8-10y, score ≤57 for children 10-15y on DCD-Q - Onset of symptoms during childhood	Other musculoskeletal, neurological, cardiorespiratory, communication or intellectual impairments affecting motor abilities
Sufficient knowledge of the Dutch language	/

Abbreviations: TD: typically developing, DCD: Developmental Coordination Disorder, DCD-Q: Developmental Coordination Disorder Questionnaire, m-ABC-2: Movement Assessment Battery for Children version two, PC: percentile.

3.3 Medical ethics

The parents of all participating children received a detailed description of the study protocol via mail or as a hand-out and were asked to sign an informed consent. The study was approved by the medical ethical committee of Hasselt University and is registered at clinicaltrials.gov (identifier: NCT04891562) and has the code B115202000000.

3.4 Study protocol

Participants were tested in two separate sessions. Each session lasted around 120 minutes. Figure 2 gives a visualization of the study protocol; further descriptions can be found in sections 3.4.1 and 3.4.2. The sessions were divided to ensure motivation and concentration in all tests. Possible adaptations in the session's duration were made in consultation with the parents to not interfere with the child's (school or hobby) schedule. Data collection took place from January 2021 till April 2, 2022.

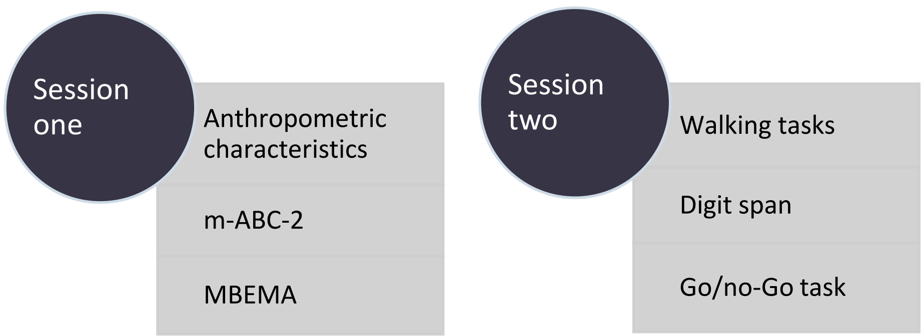

Figure 2. Study protocol

Abbreviatons: m-ABC-2: movement Assessment Battery for Children version two, MBEMA; Montreal Battery for Evaluation of Musical Abilities

3.4.1 Session one

The first session focused on collecting the anthropometric characteristics of the participants, namely age and sex. These characteristics were collected to analyze demographic differences between the DCD and TD group. Furthermore, the movement Assessment Battery for Children version 2 (m-ABC-2) and the Montreal Battery of Evaluation of Musical Abilities (MBEMA) were taken. The Developmental Coordination Disorder Questionnaire (Dutch version, Coördinatievragenlijst voor ouders) (DCD-Q) was given to the parents during the first session to be completed by the second session.

The m-ABC-2, consisting of a performance test, can be used in children from 3 to 16 years old. Tasks included in the m-ABC-2 are age-appropriate and measure manual dexterity, ball skills and balance (Wuang, Su, & Su, 2012). The performance test takes about 20 to 40 minutes. If a physical therapist had recently performed this test, the data was shared with the researchers to minimize learning effects. The m-ABC-2 was proven to be a clinically useful instrument in identifying impairments in motor performance in children (Brown & Lalor, 2009). The results of this test were used to assign the children to the TD or the DCD group.

The Developmental Coordination Questionnaire is used to assess if motor impairments negatively influence activities of daily life. The DCD-Q has a Dutch translation, the 'Coördinatievragenlijst voor ouders' (CVO), this version was used in this study. The questionnaire is a psychological assessment tool for children aged between 5 to 15 years. It is used to screen for coordination disorders and is filled in by the child's parents. The DCD-Q 2007 consists of 15 items divided into three categories: control during movement, fine motor and handwriting and general coordination. A study by Wilson et al. (2009) found that the DCD-Q 2007 is a valid screening tool for DCD.

To assess rhythm perception, the subtests melody and rhythm of the abbreviated version of the Montreal Battery of Evaluation of Musical Abilities (MBEMA-s) was performed by each participant. Each task consists of 20 unfamiliar tones. In each task, children were instructed to compare melodies and rhythms and were asked whether it was the same or different than the one they heard before. According to Peretz et al. (2013) the abbreviated MBEMA has a better sensitivity than the Montreal Battery for Evaluation Amusia for adults (MBEA) and therefore is suitable for identifying rhythm perception in children.

3.4.2 Session two

During the second session, auditory-motor coupling was assessed using three walking conditions namely walking in silence, with beats in an isochronous metronome and a non-isochronous metronome. Different metronome beats were used to distinguish auditory-motor coupling with a more discrete tone (isochronous) and a more continuous tone (non-isochronous). Research suggested that the non-isochronous metronome condition represents a more melodic tone, like in music, and that the underlying mechanism of synchronizing to a non-isochronous tone is different compared to an isochronous metronome (Torre et al, 2013).

During each condition the participant was asked to walk at a comfortable pace, the beats were then set according to the comfortable walking tempo. Between each condition, a rest period of three minutes was provided to minimize fatigue. During the metronome conditions, the child was asked to match their movement to the beat of the metronome, this is done to compare auditory-motor coupling between TD and DCD children. More information on the walking task and different conditions is provided in sections 2.4.2.1 and 2.4.2.2 respectively.

Moreover, when each condition was fulfilled, the test was repeated at different tempi of the same metronome conditions: an isochronous metronome and a non-isochronous metronome. The different tempi consisted of the comfortable tempo during walking, -10% of the walking tempo and +10% of the walking tempo. Again, after each trial, a rest period of three minutes was provided.

To keep the child motivated and concentrated on the tasks, cognitive tests were performed in between the different walking tests. The tests performed were the digit span and the Go-no/Go task. The digit span measures working memory in which children are instructed to listen to random digits and repeat these in a forward and backward manner (De Weerdt, Desoete, & Roeyers, 2013a). The Go-no/Go task is used to assess behavioral inhibition in children with limited working memory demands (De Weerdt, Desoete, & Roeyers, 2013b). This test consists of an auditory and visual subtask. Furthermore, the test consists of different trials in which the child is asked to press the spacebar of a laptop when a Go stimulus appears, but not when a no/Go stimulus appears. Performance is measured with mean reaction times, commission errors and omission errors. The cognitive tests were used to identify probable confounders for auditory-motor coupling.

3.4.2.1 Walking task

During the walking task participants were instructed to walk for three minutes on an oval path (20x15 meters). Colored cones were used to identify this walking path. During each block, children wore sensors (Physilog 5 and Gait Up) on the dorsum of each foot that measured spatiotemporal gait parameters. For familiarization with the walking path, the participants were allowed to complete one round before starting the walking task. For assessing auditory-motor coupling the software program ‘D-jogger’ was used. This is a metronome player that provides the different beats and logged and calculated step-stimuli synchronization (Moens et al., 2014).

3.4.2.2 Task conditions

3.4.2.1.1 Silent

In the silent condition, the child was instructed to walk comfortably for three minutes. No beats were played in this condition, but the child was still instructed to wear the headphones for standardization purposes. The silent condition was performed first, afterwards the order of metronome conditions were randomized.

3.4.2.1.2 Metronome

During the metronome condition, two different metronome beats were played. When walking to an isochronous beat the beat was fixed making this more predictable and discreet. Unlike the isochronous beat, the non-isochronous beat was less predictable. During this beat, an attack and release phase is added making this beat more continuous.

The tempi of the beats were set in accordance with the comfortable walking pace of the first walking task (silent condition). Afterwards the tempi were increased or decreased by ten percent to investigate auditory-motor coupling in different tempi.

3.5 Technical equipment

While performing the walking tasks, children were equipped with two wearable, Physilog5, sensors that were placed on the dorsum of each foot (figure 2). These sensors were used for measuring gait parameters. A custom-made software program, the D-Jogger (figure 3), was used for assessing gait tempo and synchronizing metronome beats to this tempo.

The Physiolog5 sensors from Gait Up are high-quality 3D accelerators, 3D gyroscopes and have barometric pressure sensors. According to Carroll, Kennedy, Koutoulas, Bui, and Kraan (2022), these sensors have a substantial agreement for stride length and velocity and almost perfect agreement for stride time. This data proves that using Physilog5 is an accurate manner for measuring gait parameters.

The D-Jogger is a technology that manages to increase or decrease the tempi of songs or metronomes to an external beat to synchronize this beat to the participant’s movements. According to Moens and Leman (2015), the D-Jogger can be used as an assistive technology in a clinical context as an auditory cue. The D-jogger consists of a software program on a laptop, headphones (Sennheiser RS 127-8) (figure 4) and two NGIMU sensors (x-io technologies) (figure 2).

Figure 2. Physilog5 sensors (lower sensors) and D-jogger NGIMU sensors (upper

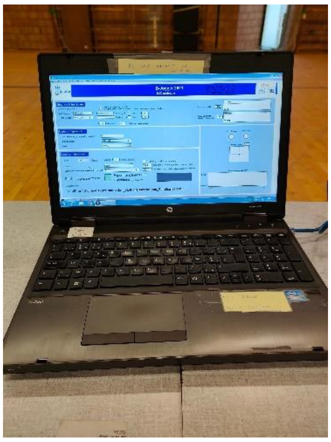

Figure 3. D-jogger software

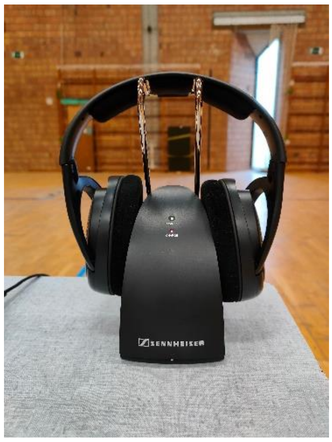

Figure 4. D-jogger headphones Sennheiser RS 127-8

3.6 Outcome measures

Auditory-motor coupling was measured using the step-stimuli synchronization parameters from the wearable sensors. To assess the ability, consistency and accuracy of this synchronization relative phase angles (RPA) and resultant vector lengths (RVL) were calculated by circular statistics during the metronome conditions (Moumdjian, Buhmann, Willems, Feys, & Leman, 2018). Perfect synchronization was defined as an identical timing of steps and beats.

The timing of the step relative to the closest beat was described by the relative phase angle (RPA). A positive phase angle indicated a step after the beat, whereas a negative relative phase angle indicated a step before the beat. Resultant vector length (RVL) expresses the stability of the relative phase angles over time. An RVL of 1 represents a high coherence of relative phase angles over time, whereas an RVL of 0 represents a multimodal distribution of relative phase angles over time indicating a more variable matching pattern of synchronizing steps to the metronome beat.

Moreover, rhythm perception was measured using the aforementioned MBEMA. This test consisted of a rhythm and melody subtask. Both subtasks were considered individually and together. Total scores per subtests are expressed by the number of good answers on 20, while the total score is expressed in percentages correct using ((rhythm + melody)/40) * 100%. More correct answers indicated a better rhythm perception.

Lastly, the link between rhythm perception and auditory-motor coupling was assessed by investigating whether children that had a better rhythm perception performed better in the auditory-motor coupling task.

3.7 Statistical analysis

Anthropometric characteristics were tested for group differences in age, gender, m-abc, DCDQ, Go/no-Go, Digit span and following musical classes. Continuous data like age, m-abc, DCDQ, Go/no-Go and Digit span were tested for normality of data and equal variances. A student's T tests was used when the normality of data or residuals was achieved and variances were equal. The Fisher's exact test was used for testing differences in gender since this is a nominal data set. When data nor residues were normally distributed but variances were equal, a Wilcoxon signed rank test was used. In the case of normally distributed data but no equal variances, the Welch test was performed. For assessing between group differences in following musical classes, a contingency table was used since this is a dichotomous variable.

For investigating the research questions, first model assumptions were tested. When data was normally distributed and variances were equal, a mixed model was used since we included continuous and categorical data and performed repeated measures. In the case of no normal distribution but equal variances, a Wilcoxon signed rank test was used for testing between-group differences.

For the first research question, namely to examine possible differences in rhythm perception (total MBEMA scores) between groups, a mixed model (main effect group, main effect age, main effect gender, main effect Digit Span Forward, main effect of following musical classes, interaction effect group*age, interaction effect group*gender, interaction effect group*Digit Span Forward, interaction effect group*musical classes, random effect participant ID) was used as data was normally distributed and variances were equal. Testing between-group differences in the rhythm and melody subtask was performed via the Wilcoxon signed rank test since data was not normally distributed but variances were equal.

Our second research question, namely assessing differences between groups in auditory-motor coupling ability and consistency (RPA, RVL) in the comfortable walking pace condition, a within-group and between-group repeated measures design in a mixed model was used (main effect group, main effect metronome type, interaction effect group*metronome type, random effect participant ID). Given that the data of RVL and relative phase angles were not normally distributed in the +10% and -10% conditions, the Wilcoxon signed rank test was used. Unfortunately, this meant that confounding factors could not be described.

Our third research question, more specific, investigating a possible link between rhythm perception and auditory-motor coupling, was examined by using a linear regression.

A visualization of the used statistical tests can be found in figure 5. The confidence interval was set at 95% and significance level at $p = 0.05$. Statistical analysis was done using the JMP-SAS 16.2 software.

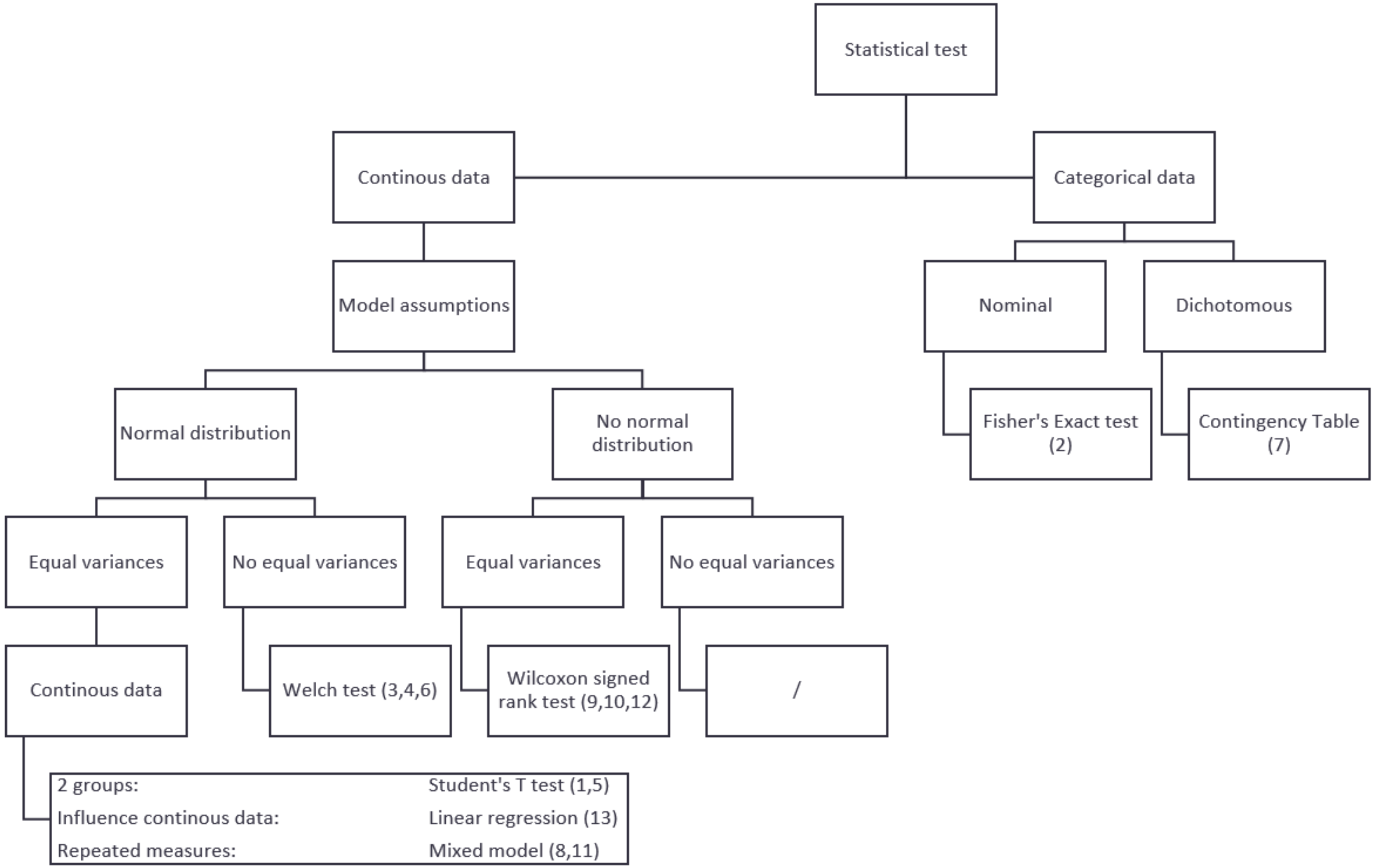

Figure 5. Visualization of selection of statistical test

Abbreviations: 1: age, 2: gender, 3: m-abc, 4: DCDQ, 5: Go/no-Go, 6: Digit Span 7: musical classes, 8: rhythm perception total MBEMA%, 9: melody subtask, 10: rhythm subtask, 11: auditory-motor coupling in comfortable walking pace, 12; auditory-motor coupling in +10% condition, 13: auditory-motor coupling in -10% condition, 13: link between rhythm perception and auditory-motor coupling.

4. Results

4.1 Participants

A total of 42 children were screened of which 17 children were excluded. Children were excluded based on a) discrepancies between m-ABC-2 score and the DCD-Q (n=7); b) missing data (n=3) and c) comorbidities that affected motor abilities or testing protocol, more specific ASD (n=1), neurofibromatosis type 1 (n=1), multiple complex developmental disorder (n=1) and cerebral visual impairments (n=1) (Haas-Lude et al., 2018; Kaur, S, & A, 2018; Marchand-Krynski, Morin-Moncet, Bélanger, Beauchamp, & Leonard, 2017; Rietman et al., 2017).

Children with comorbidity of ADD or ADHD were included as it is found to not interfere with this study's purpose. Children with a diagnosis of ADD children were found to have a normal motor speed performance, however, they had impairments in coordination of unimanual and bimanual tasks (Marchand-Krynski et al., 2017). Nevertheless, when learning new motor skills children with ADD improved at the same level as TD children (Marchand-Krynski et al., 2017). Since bimanual and unimanual tasks were not included in our study's protocol children with ADD were included. Children with an ADHD comorbidity were included as well because of the high prevalence of ADHD-DCD comorbidity combination (Barkley, 2006). Research suggests that ADHD and DCD share a strong additive genetic component (Martin, Piek, & Hay, 2006).

Other reasons for exclusion during testing were behavioral issues (n=1) and not speaking Dutch as their mother language (n=2). This finally led to a total of 25 participants, with the classification of 14 children in the TD group and 11 children in the DCD group. A visualization of the selection procedure is given in figure 6.

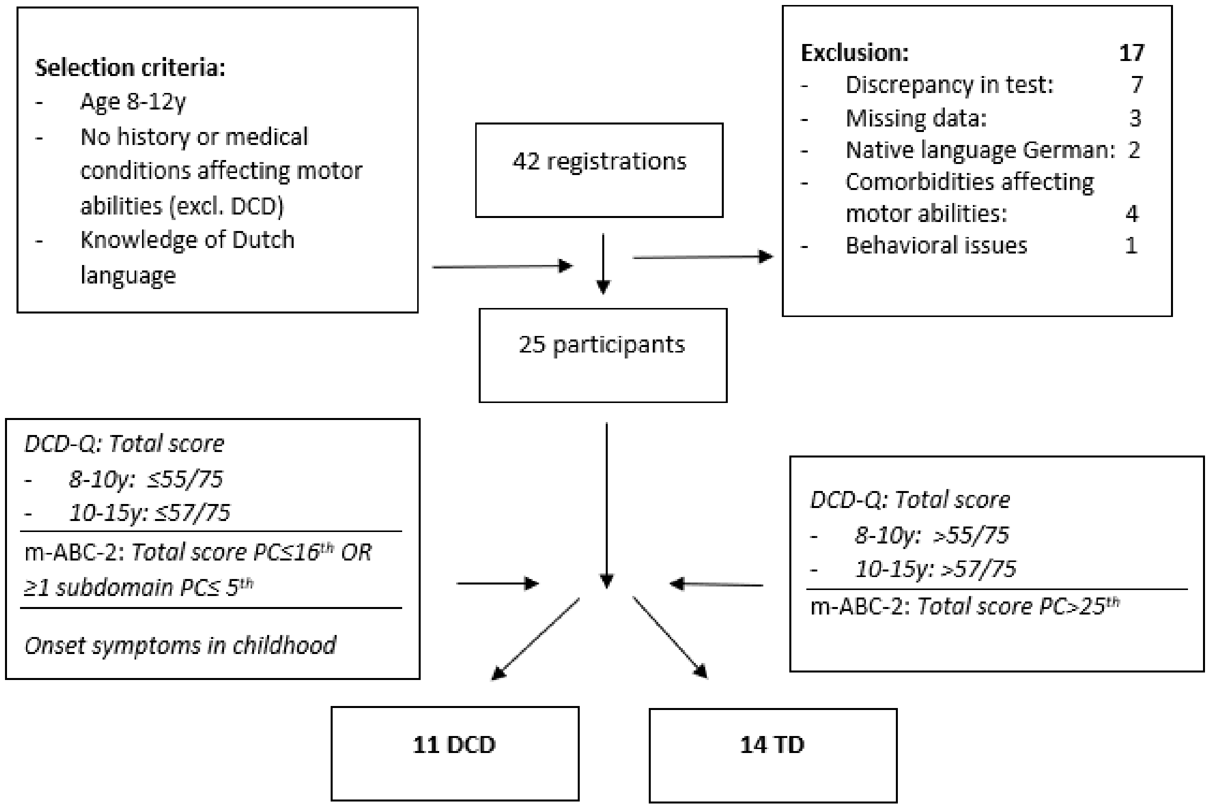

Figure 6. Visualization of selection procedure

Abbreviations: DCD: Developmental Coordination Disorder, TD: typically developing, m-ABC-2: movement Assessment Battery for Children version 2, DCD-Q: Developmental Coordination Disorder Questionnaire.

After statistical analysis of the anthropometric characteristics of the DCD and TD group, no significant intergroup difference was found for age (p=0.5931). However, significant intergroup differences were found for the total scores of the m-ABC-22 (p<0.001) and DCD-Q (p<0.001). DCD children scored significantly lower on these tests compared to TD children. These results were as predicted because the classification of the groups is based on the results of these tests. Also, for gender, a significant intergroup difference was found (p=0.0419). There was an overrepresentation of males in the DCD-group compared to TD-group. A summary of the anthropometric characteristics is shown in table 2.

Table 2

Anthropometric characteristics

	DCD (mean±SD)	TD (mean±SD)	P-value	Statistical test
Participants	11	14	/	/
Age (years)	10.12±1.27	10.39±1.21	0.5931	T-test
Gender (% male)	81.82	35,71	**0.0419***	Fisher's Exact test
m-ABC2 (PC)	6.79±8.61	59.07±21.12	**<0.001***	Welch's test
DCD-Q	35.91±10.18	69.93±3.47	**<0.001***	Welch's test
Go/no-Go (aud)	55.27 ± 6.01	59.29±0.81	**0.0052***	T-test
Digit Span (FW)	8±2.35	6.43±1.20	**0.0078***	Welch's test
Musical classes (% n)	72.73	71.43	0.4734	Contingency table

*p-value <0.05 indicates a significant difference between both groups (CI=95%)

Abbreviatons: m-ABC2: movement Assessment Battery for Children version 2, PC: percentile, DCD-Q: Developmental Coordination Disorder Questionnaire

4.2 Rhythm perception

For the total MBEMA score, a significant group effect (p=0.0301; effect size= 0.05492) as well as interactions for group*age (p=0.0076; effect size= 0.08575), group*gender (p=0.0004; effect size=0.16274), group*working memory (p=0.0014; effect size=0.12728) and group*musical classes (p=0.0216; effect size= 0.06210) was found. These results suggest that younger DCD children, female DCD children, DCD children who have a lower working memory and DCD children who do not follow musical classes score lower on the total MBEMA score. Table 3 provides an overview of the results we obtained after the analysis of rhythm perception. Furthermore, a visual representation can be found in appendix B, part 1.

In the melody subtask, no significant between-group difference was found (p=0.3901). Even distributed by having had musical classes, children in the DCD group did not differ significantly from children in the TD group when following musical lessons (p=0.1205) and when they did not (p=0.8590). In the rhythm subtasks, the results were similar. No significant between-group difference was found (p=0.2069), distributed by children who did not follow musical classes (p=0.1559) and for children who did follow musical classes (p=0.8050).

Table 3

Comparison of the total score on the MBEMA between TD and DCD children (Mixed Model)

	TD	DCD
Mean ± SD	76.07±13.80	74.32 ± 16.59
	P-values (TD vs. DCD)	**Effect size**
Group	**0.0301***	0.05492
Age	**0.0013***	0.12969
Musical classes y/n	**<0.0001***	0.20546
Group*age	**0.0076***	0.08575
Group*gender	**0.0004***	0.16274
Group*working memory	**0.0014***	0.12728
Group*musical classes	**0.0216***	0.06210

**p-value <0.05 indicates a significant difference between both groups (CI=95%)*

Abbreviations: TD: typically developing, DCD: Developmental Coordination Disorder, MBEMA: Montreal Battery for Evaluation of Musical Abilities

4.3 Auditory-motor coupling

4.3.1 Auditory-motor coupling in comfortable walking pace

Auditory-motor coupling ability (RPA) in DCD children compared to TD controls showed no significant group effect (=0.6957; effect size= 0.00395), but a significant interaction for group*metronome type (p=0.0158; effect size=0.07183) was found. This interaction indicates that children in the DCD group synchronized worse during the isochronous metronome condition. An overview of the results for rhythm synchronizing ability can be found in table 4. Furthermore, a visual representation can be found in appendix B, part 2, figure 1.

To analyze the synchronization variability (RVL), a mixed model was used since data were not independent. No significant confounding effects were found for age, gender, working memory, metronome beat and impulse control. Therefore, a T-test was used for testing group differences. A significant difference between groups was found (p=0.0061). This suggests that DCD children have a higher variability when synchronizing steps to the beat compared to TD controls. Table 5 provides an overview of the results obtained for rhythm synchronizing variabilities. A visual representation of the result can be found in appendix B, part 2, figure 2.

Table 4

Comparison of rhythm synchronizing ability (RPA) in comforting walking speed for both conditions between TD and DCD children (Mixed Model)

	TD	**DCD**
Mean ± SD	-21.72 ± 31.10	-16.35 ± 55.14
	P-values (TD vs. DCD)	**Effect size**
Group	0.6957	0.00395
Metronome Type	**0.0024***	0.12292
Group*Metronome type	**0.0158***	0.07183

**p-value <0.05 indicates a significant difference between both groups (CI=95%)*
Abbreviations: TD: typically developing, DCD: Developmental Coordination Disorder, RPA: relative phase angle

Table 5

Comparison of rhythm synchronizing variabilities (mean RVL) in comforting walking speed for both conditions between TD and DCD children (T-test)

	Mean ±SD DCD	**Mean ±SD TD**	**P-values (TD vs DCD)**	**Effect size**
DCD	0.53 ± 0.31	0.74 ± 0.24	**0.0061***	**

**p-value <0.05 indicates a significant difference between both groups (CI=95%)*
*** The effect size could not be calculated because of statistical analysis with a T-test.*
Abbreviations: TD: typically developing, DCD: Developmental Coordination Disorder RVL: resultant vector length

4.3.2 Auditory-motor coupling in +10% condition

Since there was no normal distribution of data nor residues, but variances were equal, a Wilcoxon signed-rank test was performed. Unfortunately, confounding factors could not be predicted using this manner. Data were stratified by metronome type since this appeared to be a significant confounding effect in the comfortable walking pace condition.

For the non-isochronous metronome condition, there was no significant between-group difference for matching each step to the beat (p=0.7220) (RPA) and no between-group difference was found for variability (RVL) in synchronizing each step to the non-isochronous metronome beat(p=0.0624), but there was a trend where children with DCD were more variable in synchronizing to the metronome beat at +10% of their comfortable walking pace.

In the isochronous metronome condition, we found no significant between-group difference for synchronization (RPA) (p=0.8480) and variability of synchronization (RVL) (p=0.0552), but this nearly reached significance. Suggesting that children with DCD are more variable in synchronizing their steps to the isochronous metronome. An overview of the previous results can be found in table 6. Furthermore, a visual representation of the results for ability and variability can be found in separate figures in appendix B, part 3.

Table 6

Comparison of rhythm synchronizing abilities and variabilities in +10% walking speed for both conditions between TD and DCD children (Wilcoxon signed rank test)

	TD	**DCD**
Mean RPA – ISO ± SD	17.99 ± 33.40	9.92 ± 52.14
Mean RPA – NON-ISO ± SD	41.37 ± 37.32	53.61 ± 52.37
Mean RVL – ISO ± SD	0.71 ± 0.26	0.45 ± 0.32
Mean RVL – NON-ISO ± SD	0.69 ± 0.27	0.47 ± 0.31
	P-values (TD vs. DCD)	**Effect size**
Non-isochronous metronome		
Relative Phase Angle	0.7220	**
Resultant Vector Length	0.0624	**
Isochronous metronome		
Relative Phase Angle	0.8480	**
Resultant Vector Length	0.0552	**

***The effect size could not be calculated because of statistical analysis with a Wilcoxon signed rank test.*
Abbreviations: TD: typically developing, DCD: Developmental Coordination Disorder, ISO: isochronous metronome, NON-ISO: non-isochronous metronome, SD: standard deviation

4.3.3 Auditory-motor coupling in -10% condition

For the non-isochronous metronome condition, data were not normally distributed but variances where equal. Therefore, a Wilcoxon signed rank test was performed for both the ability to synchronize and variability of synchronization, but confounders could not be predicted. Using this statistical test, a significant between group difference was found for synchronization (RPA) (p=0.0048), but not for variability in synchronization (RVL) (p=0.2282). This indicates that matching steps to the non-isochronous metronome beat is worse in children with DCD, but not more variable than TD controls.

Data from the isochronous metronome condition was not normally distributed for the synchronization data. No between group difference was found for synchronizing (RPA) steps to the beat (p=0.1798). Data assessing variability of synchronization (RVL) was normally distributed so a mixed model could be used for assessing group differences and confounding effects. Again, no main group effect (DCD- TD) was found (p=0.3598; effect size=0.03141), but age proved to be a significant confounding effect (p=0.0463; effect size=0.16009). No significant effects were found for other confounding variables like gender, working memory and impulse control. Variability in synchronizing to the isochronous metronome beat is thus explained by age rather than by group. Table 7 provides an overview of the previous results, whereas separate visual representations for ability and variability can be found in appendix B, part 4.

Table 7

Comparison of rhythm synchronizing abilities and variabilities in -10% walking speed for both conditions between TD and DCD children (Mixed models & Wilcoxon signed rank test)

	TD	**DCD**
Mean RPA – ISO ± SD	-84.36 ± 36.18	-43.22 ± 76.92
Mean RPA – NON-ISO ± SD	-80.02 ± 29.98	-41.87 ± 43.33
Mean RVL – ISO ± SD	0.56 ± 0.30	0.35 ± 0.29
Mean RVL – NON-ISO ± SD	0.55 ± 0.31	0.42 ± 0.31
	P-values (TD vs. DCD)	**Effect size**
Non-isochronous metronome		
Relative Phase Angle°	**0.0048***	**
Group (RVL)°	0.2282	**
Isochronous metronome		
Relative Phase Angle°	0.1798	**
Group (RVL)	0.3598	0.03141
Age	**0.0463***	0.16009

**p-value <0.05 indicates a significant difference between both groups (CI=95%)*
*** The effect size could not be calculated because of statistical analysis with a Wilcoxon signed rank test*
°Wilcoxon signed rank test

4.3 Link between rhythm perception and auditory-motor coupling

The link between rhythm perception and auditory-motor coupling is investigated in both groups for the different types of metronome conditions. In the DCD group, when synchronizing to the non-isochronous metronome, there was no significant correlation between rhythm perception and auditory-motor coupling ability (RPA) ($p=0.3527$; $r^2=0.096436$) or synchronization variability (RVL) ($p=0.3322$; $r^2=0.104516$). This indicates that the ability and variability of synchronizing to the metronome beat is not influenced by the ability for rhythm perception. For the TD group, no significant correlation was found for synchronizing (RPA) to the non-isochronous metronome beat ($p=0.6066$; $r^2=0.022765$) but a significant correlation was found for synchronization variability (RVL) ($p=0.0100$; $r^2=0.437652$), indicating that TD children who are better rhythm perceivers are better in consistently synchronizing their steps to the non-isochronous metronome beat.

In the isochronous metronome condition, no significant correlation between rhythm perception and auditory-motor coupling ability (RPA) was found for the DCD group ($p=0.2695$; $r^2=0.133346$), nor for synchronization variability (RVL) ($p=0.2051$; $r^2=0.171698$). Again, indicating that the ability and variability of children with DCD to synchronize to the metronome beat is independent of rhythm perception. Lastly, for children in the TD group when synchronizing to the isochronous metronome, there was no significant interaction found (RPA) ($p=0.7723$; $r^2=0.007248$) nor for synchronization variability (RVL) ($p=0.0514$; $r^2=0.280576$), but this nearly reached significance. There was thus a trend where children who synchronized less variable to the metronome beat where better in rhythm perception. A visual representation of the previous results is provided in figure 7 and 8.

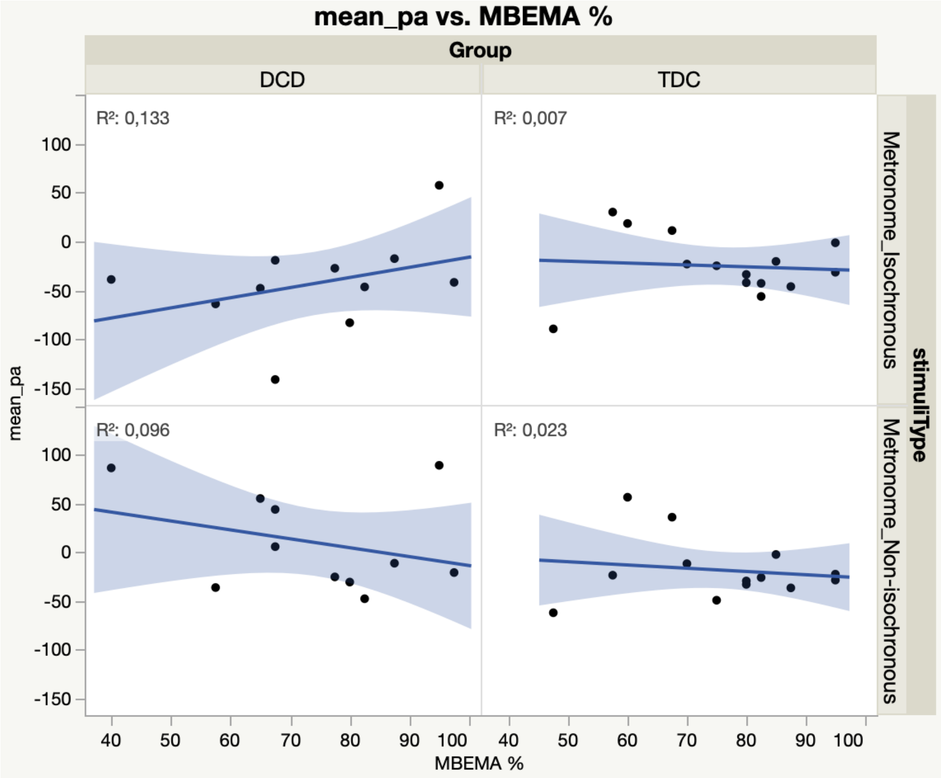

Figure 7. Visual representation of the link between rhythm perception and auditory-motor coupling ability in both groups.

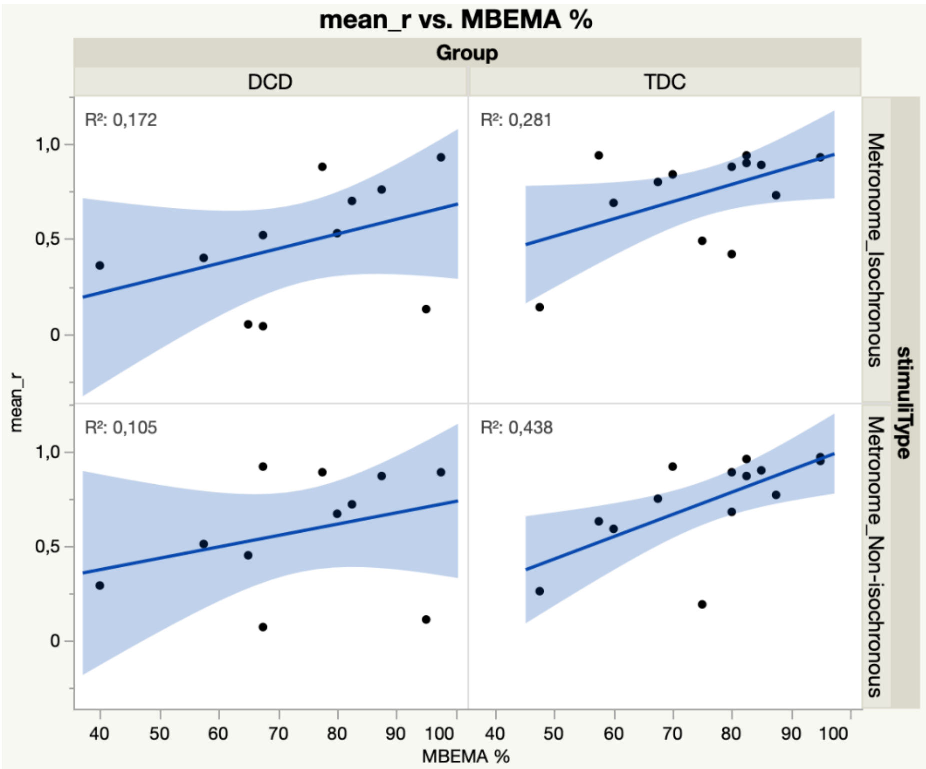

Figure 8. Visual representation of the link between rhythm perception and auditory-motor coupling variability in both groups

5. Discussion

This study aimed to investigate differences in rhythm perception and auditory-motor coupling in DCD children compared to TD children. Moreover, the link between rhythm perception and auditory-motor coupling was investigated. Not much research is available assessing these abilities in children with DCD during a walking test, because most test protocols in the available research use tapping tasks. This study was performed with the aim to reduce the gap in literature about this topic.

In this study, significant differences were found for rhythm perception in children with DCD compared to TD children. Previous research comparing rhythm perception in DCD and TD children was performed. In a study by Roche et al. (2016) participants were instructed to compare rhythms in a stair cased manner on the one hand and on the other hand rhythm perception thresholds were compared between children with DC and TD children. They found no significant group difference suggesting that TD and DCD children have similar rhythm perception abilities. Whereas, Chang et al. (2021) found that DCD children showed lower auditory perceptual thresholds in rhythm discrimination and duration discrimination compared to TD children. Their results were similar to this study's findings. The auditory perceptual thresholds were assessed using different duration discrimination, rhythm discrimination and pitch discrimination tasks. Possible reasons for the contradictory findings on rhythm perception could be explained by the different rhythm perception protocols used in these studies. Roche et al (2016) and Chang et al (2021) used no standardized test for measuring rhythm perception but used different tasks, whereas this study used the standardized MBEMA test.

Rhythm perception was in this research examined with the abbreviated version of the MBEMA. Peretz et al. (2013) states that this battery is objective, short and child-friendly and can be used in both healthy and clinical populations across cultures. Therefore, they find it suitable to assess musical perception in children. By using stimuli that focus on music discrimination rather than emotional discrimination (Gosselin, Paquette, & Peretz, 2015), potential confounding influence of emotional valence is limited in this test (Jamey et al., 2019). Except for Peretz et al. (2013) stating that the abbreviated MBEMA has a better sensitivity than the Montreal Battery for Evaluation Amusia for adults (MBEA), no other research has been conducted to assess the psychometric properties of this battery.

Our second aim of this study was to compare auditory-motor coupling abilities of TD children to children with DCD. Previous research of Whitall et al. (2006) demonstrated that children with DCD were more variable in tapping to a metronome beat than children with TD. This aforementioned study used a fixed metronome, in our study described as the isochronous beat, for measuring auditory-motor coupling. Similarly, the significant group*metronome type interaction found in the results indicate a higher variability for DCD children when synchronizing to a metronome beat. Suggesting that children with DCD are indeed less stable in matching their movements to a fixed metronome beat. The same phenomenon was found by Whitall et al. (2008), where participants were instructed to clap to the fixed metronome beat. They found that children with DCD did not differ in how closely they matched their clap to the beat but found significant differences in variability of this synchronization. Again, our results were similar as we found no difference in matching steps to the metronome beat but DCD children were significantly more variable in synchronization. No studies were performed using a more continuous, non-isochronous metronome beat for investigating auditory-motor coupling in children with DCD. Research showed that synchronizing to a more continuous metronome beat occurs differently to a fixed beat. Where synchronization to a non-isochronous metronome uses feedback from previous 'missed' steps to the beat and correcting these in the following phase, synchronization to an isochronous metronome uses continuous coupling to the metronome beat (Marmelat, 2014).

For evaluating auditory-motor coupling, a walking task to the beat of a metronome was used. To present day, there is only one study available that examined auditory-motor coupling by using a walking task in children (Whitall et al., 2006). Nevertheless, the study set-up used in the study of Whitall et al. (2006) differed from our study set-up, since they used a dual motor task where children with DCD and TD children had to clap and march to a specific beat. This methodology was previously used in other studies (Getchell, McMenamin, & Whitall, 2005; Getchell & Whitall, 2003). Likewise, to the MBEMA, no research has been conducted to assess the psychometric properties of this task. Therefore, it is impossible for us to conclude of the tests used in this research are valid for testing rhythm perception and auditory-motor coupling. This can be seen as a limitation of our study.

Lastly, this research examined the link between rhythm perception and auditory-motor coupling. This links was not much reported in research. Puyjarinet et al. (2017) performed the 'The Battery for the Assessment of Auditory and Sensorimotor Timing Abilities' (BAASTA) test protocol, which includes rhythm perception subtasks and auditory-motor perception subtasks. They found that lower synchronization performances where not only explained by more motor performance variability, indicating that rhythm perception has an effect on the ability to synchronize with rhythms. Although direct effects of rhythm perception performance on auditory-motor coupling were not investigated, they assumed there could be a possible influence. In the contrary, our results suggest no correlation between the variability of auditory-motor coupling and rhythm perception in children with DCD. The different conclusions can be explained by different protocols for investigating this link, also by differences in participants. In the study by Puyjarinet et al. (2017) this link was investigated in children with ADHD-DCD comorbidities, whereas in our study we only had one participant with this comorbidity combination and the other participants were only diagnosed with DCD. Reporting bias could have impacted these contradictory findings as well.

In this study, the coordination of gait during synchronizing steps to the metronome beats were not taken into account since coordination was beyond the scope of this research. Coordination can be seen as a contributing factor of auditory-motor coupling abilities. Research investigating the influence of coordination on auditory-motor coupling tasks is necessary for possible integration into treatment protocols. When coordination improves during synchronizing to a metronome beat, there would be indications for implementing external rhythms in treatments for DCD children.

A few studies have already examined the effect of using external rhythms on motor performance. Research by Roerdink, Lamoth, Kwakkel, van Wieringen, and Beek (2007) states that walking to the beat of a metronome can improve the interlimb coordination. Other research in children also confirms the positive effects of auditory signals, such as rhythms, on the coordination (Getchell, 2007). The results of this present study indicate that there is no link between rhythm perception and auditory-motor coupling in children with DCD, but it might be that training rhythm perception could have a positive effect on auditory-motor coupling on one hand and coordination on the other hand. It is in fact hypothesized that the motor deficits of children with DCD are a consequence of poor (timing) perception (Trainor et al., 2018). Multiple studies have examined the effect of rhythmic cueing on motor performance. For example, Whitall, McCombe Waller, Silver, and Macko (2000) examined the effect of auditory cueing on motor function in people with stroke. They reported an improvement of motor function when applying auditory cueing in rehabilitation. This research is supported by more recent research of Shahine and Shafshak (2014), who reported significant improvements on motor performance. Furthermore, research for examining the effect of rhythm interventions on motor performance in children with Autism

Spectrum Disorder reports a positive outcome, seen in a better score on coordination subpart of the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) (Srinivasan et al., 2015).

Preliminary results by dra. Mieke Goetschalckx using the same protocol set-up, suggest that children have improved gait coordination when matching their steps to a metronome beat compared to walking in silence. This improvement is stronger in DCD children compared to TD children.

5.1 Limitations and strengths

5.1.1 Limitations

Since only 25 children participated in this study, 11 in the DCD subgroup and 14 in the TD subgroup, the expected group count of 30 was not reached. This impacts the study's power. In general, a power of 0.8 is acceptable, with an alpha level of 0.05 for achieving a power of 0.8 the TD group would have needed 30 participants and the DCD group 29. Statistical power describes the probability that found effects actually exist. Power calculations performed regarding the first research question showed a power of 0.0685, which is very low. Secondly, power calculations for the second research question show a power of 0.2638 for the non-isochronous metronome condition and a power of 0.6360 for the isochronous metronome condition. Lastly, power analysis could not be performed for the third research question, given that no data was available from previous studies because no study performed an analysis of the link between rhythm perception and auditory-motor coupling. Therefore, results of this study need to be carefully interpretated.

Careful interpretation of results assessing auditory-motor coupling in the different tempi is necessary, since the risk on type 1 errors is increased due to the inability to account for within group repeated measures for the different tempi. This is due to the fact that we had to split these results because data in the -10% and +10% condition were not normally distributed.

Moreover, effect sizes were very small and could not be calculated for every result. Indicating that differences found in our samples do not necessarily mean that these differences have a clinically relevant impact. In small studies like ours, effect sizes are highly variable. Although small sample sizes mostly generate higher effect sizes because of their high variability this was not the case in this study. Indicating that the reliability of our effect sizes is okay (Slavin & Smith, 2009).

Furthermore, an unequal distribution of gender was present in this study. The DCD group consisted of approximately 80% males and in the TD group this was approximately 36%. Statistical analysis showed no significant main effect of gender on our outcome measures but given that this study's power is limited, confounding factors could not be ruled out completely.

In our previous literature search we examined possible rhythm perception and synchronization tasks. There is one battery that is proven to be sensitive for measuring poor perceptual and sensorimotor timing skills (Dalla Bella et al. 2017). This battery is named The Battery for the Assessment of Auditory and Sensorimotor Timing Abilities (BAASTA). The BAASTA is a test battery consisting of several tasks for evaluating rhythm perception and auditory-motor coupling. The perception tasks include duration discrimination, anisochrony detection with tones and anisochrony detection with music. Furthermore, auditory-motor coupling is evaluated with a beat alignment task (BAT), unpaced tapping, paced tapping to an isochronous sequence, paced tapping to music, synchronization-continuation and adaptive tapping. The battery thus consists of multiple tests for examining rhythm perception and synchronization, this is an added value when examining differences between children with TD and DCD children. Unfortunately, this test was not freely available and therefore not used in this study. Not being able to use this test could have led to making measurement errors. Limited evidence available for this study's protocol supports this risk of bias.

In this study, selection bias is present. Participants in this study were recruited from sports centra among other places, where children with DCD are most likely under represented. Furthermore, confounding biases exists as well. For some outcome measures no statistical analysis of confounding factors could be performed because of no normally distributed data, increasing the risk of confounding bias. Blinding of participants and assessors was hardly possible, increasing the risk of performance bias and detection bias.

5.1.2 Strengths

This study updates research on rhythm perception and auditory-motor coupling in children with DCD.

Randomization of walking tasks and performing the digit span and Go/no-Go tasks in between walking blocks ensured that motivation and concentration was high during all testing conditions reducing the risk of confounding bias. Moreover, we used standardized tests for checking inclusion and exclusion criteria. A study by Wilson et al. (2009) stated that the DCD-Q is a valid screening tool for DCD, furthermore the m-ABC-2 is also proven to be a clinically useful instrument for identifying impairments in motor performance of children (Brown & Lalor, 2009). Using these standardized tests ensured that participating children were included in the right subgroup.

Usage of the D-jogger technology is a strength as well, since this technology is useful in matching metronome beats to the walking pace of the participant. Moens et al. (2014) deemed the D-jogger as accurate and maximum error sufficient. On the other hand, the Physilog5 sensors have a great accuracy in measuring gait parameters (Carroll et al., 2022). This is the case as long as participants didn't hop over path markers during the walking task. To minimize chances of this happening, children were instructed to walk beside these maskers.

6. Conclusion

The results of this study conclude that there is a difference in rhythm perception, assessed with total scores on the MBEMA, in children with DCD compared to TD controls, however on melody and rhythm subtests both groups did not differ significantly. Secondly, there were no differences in matching steps to the metronome beat in children with DCD compared to TD controls during the comfortable walking pace condition, however the significant group*metronome type interaction showed that children with DCD synchronized worse to an isochronous metronome beat. Furthermore, children with DCD were less stable in synchronizing steps to the metronome beats compared to TD children. Synchronization ability and variability were not confounded by age, gender, working memory and impulse control in the comfortable walking pace condition. Lastly, we found no correlation between rhythm perception and auditory-motor coupling in children with DCD for both metronome conditions, nor for synchronization variability. Further higher quality research is recommended.

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Appendices

Appendix A: Flowchart of the selection procedure.

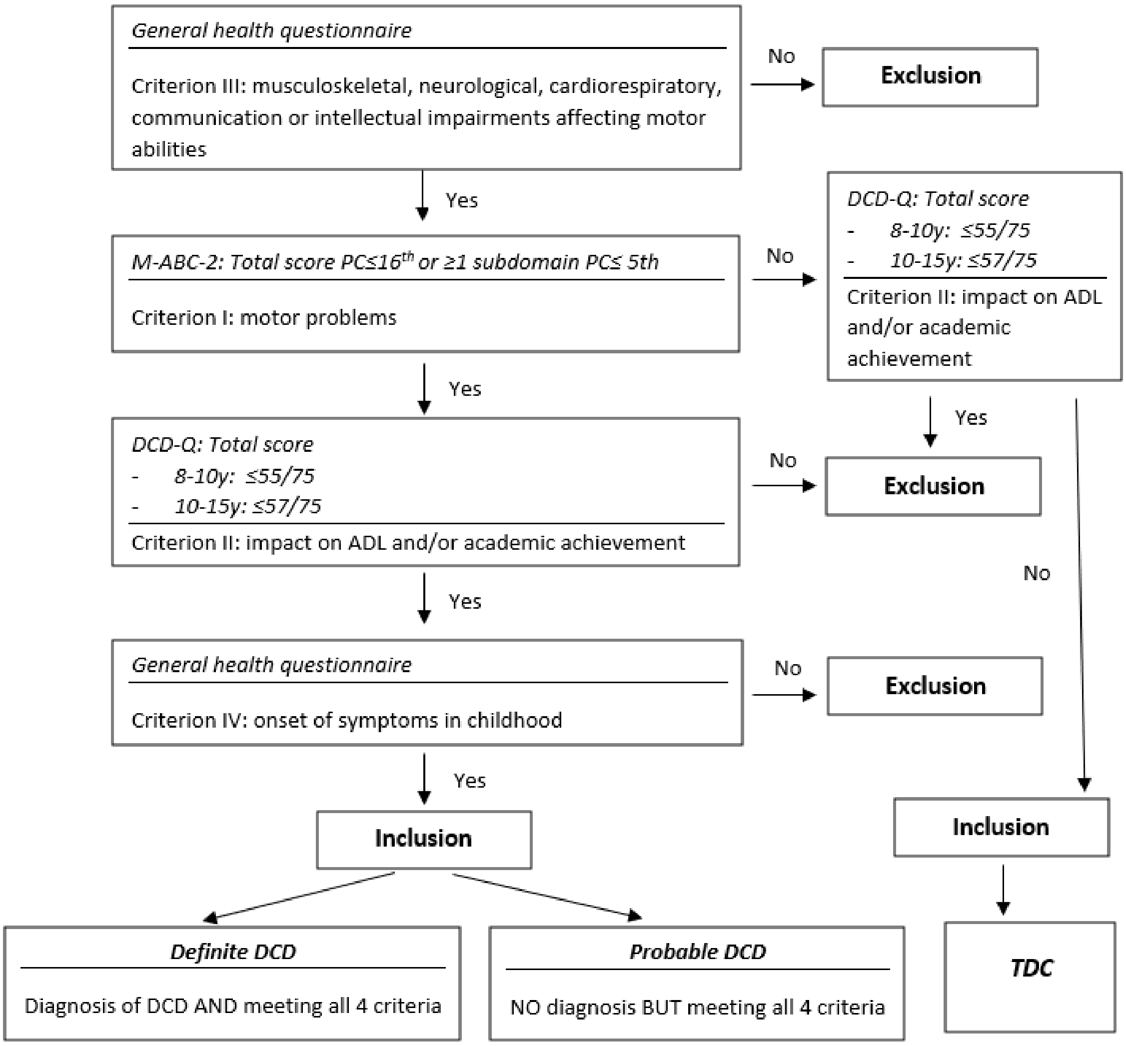


Figure 1. Flowchart of the selection procedure

Abbreviations: m-ABC2: Movement Assessment Battery for Children version 2, PC: percentile, DCD-Q: Developmental Coordination Disorder Questionnaire, TDC: typically developing children, DCD: Developmental Coordination Disorder, ADL: activities of daily living.

Appendix B: Visual representations of the results

1. Rhythm perception

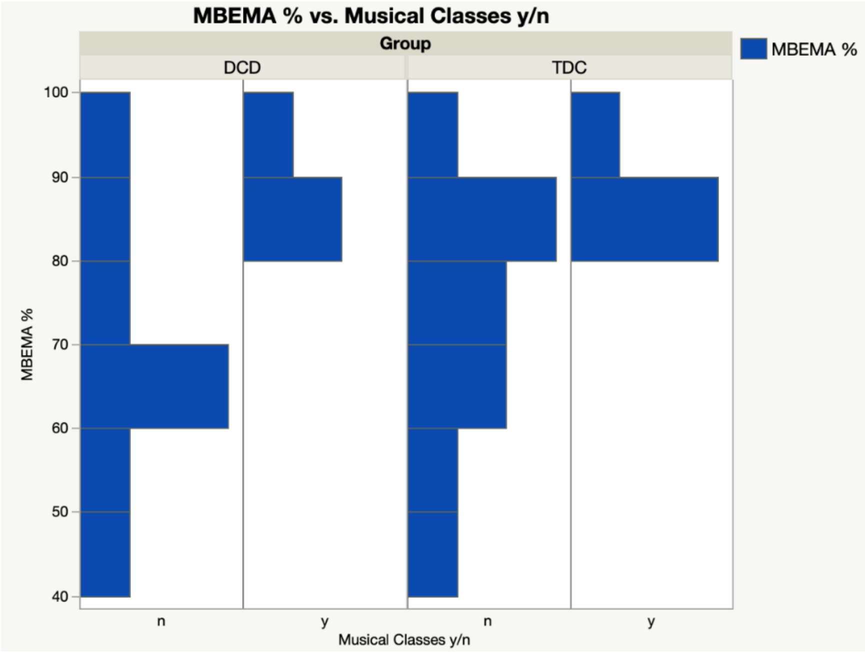


Figure 1. Visual representation of the MBEMA total % correct for both groups

2. Auditory motor coupling in comfortable walking pace condition

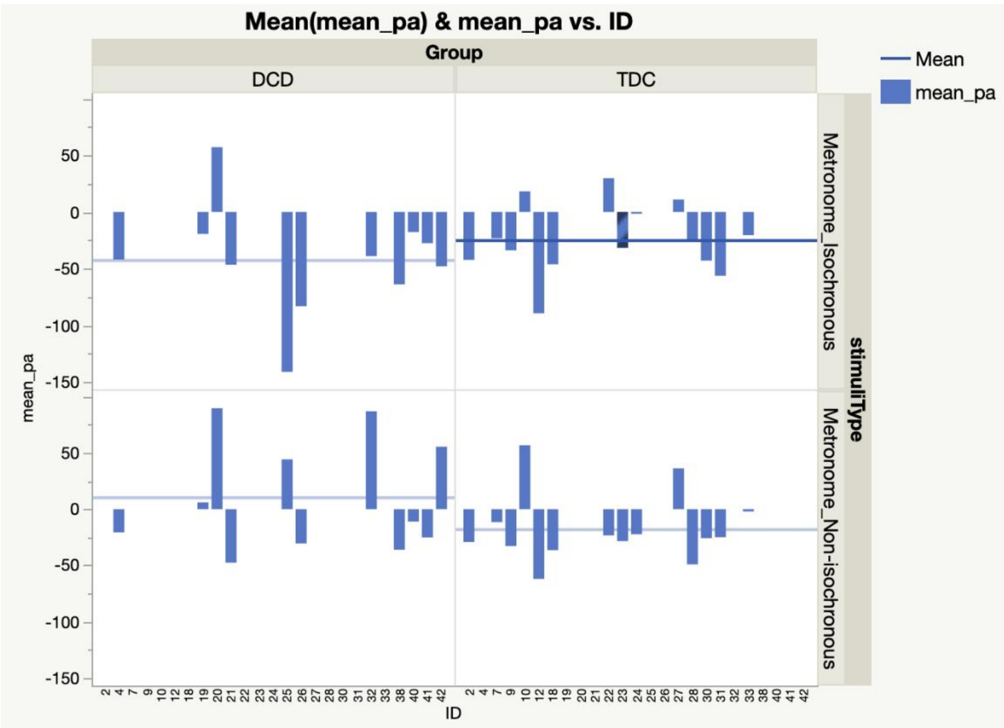


Figure 1. Visual representation of the auditory motor coupling ability (RPA) for both groups in the comfortable walking pace condition

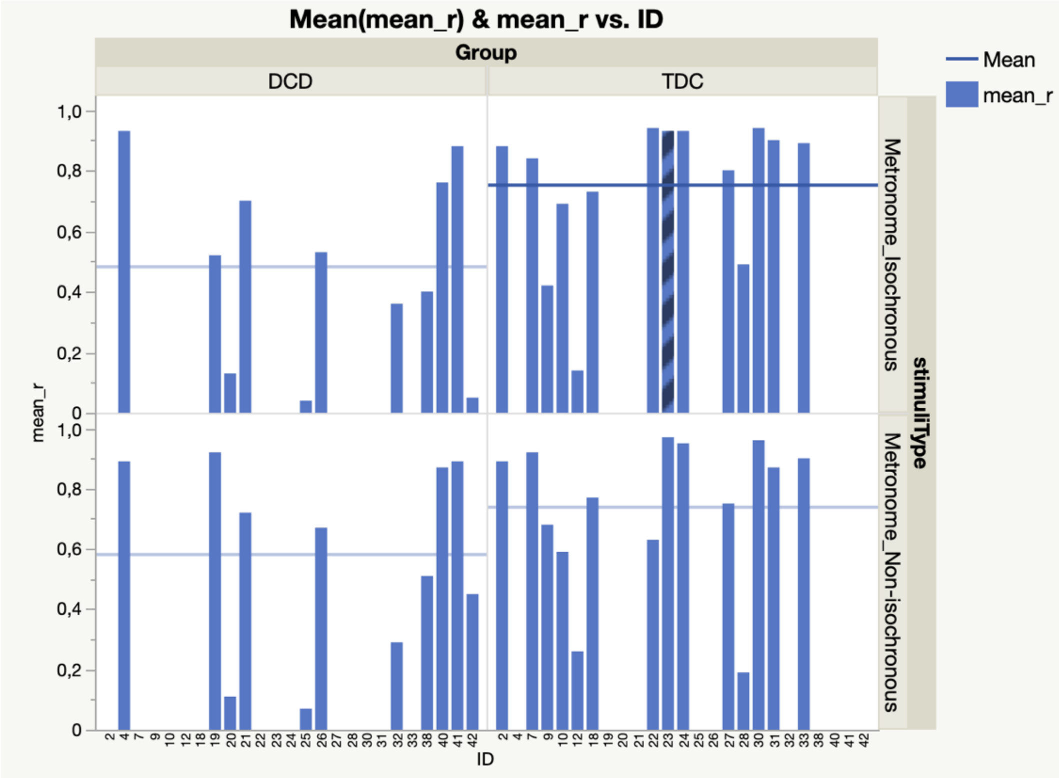


Figure 2. Visual representation of the auditory motor coupling variability (PVL) for both groups in the comfortable walking pace condition

3. Auditory motor coupling in +10% condition

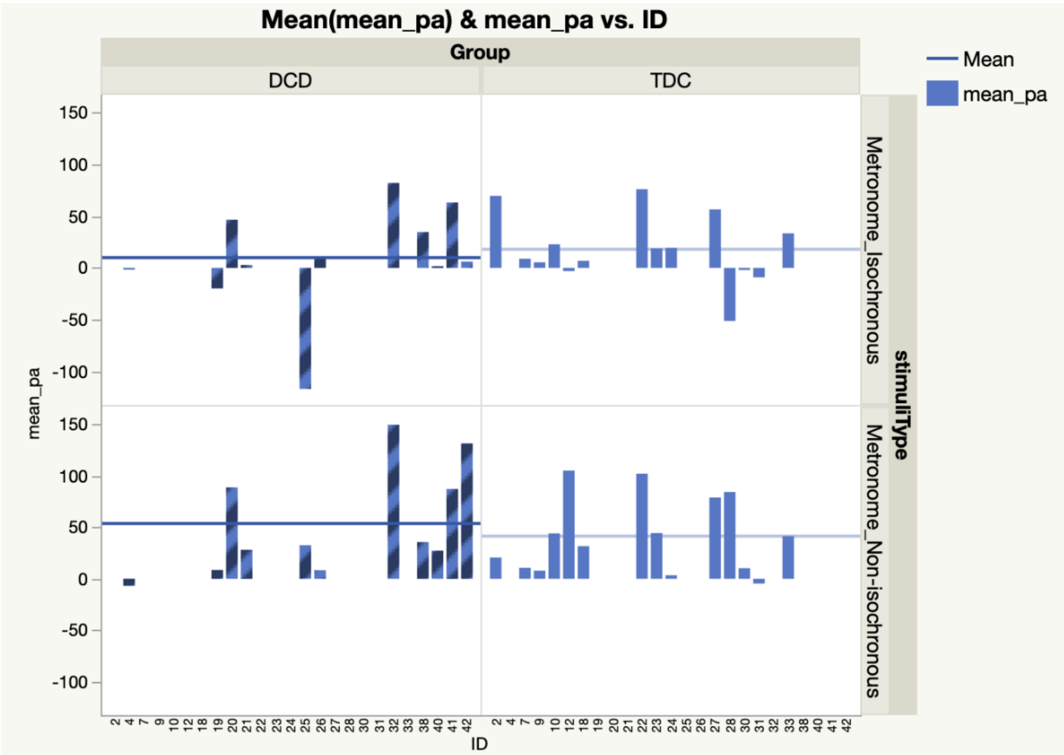


Figure 1. Visual representation of the auditory motor coupling ability (RPA) for both groups in the +10% condition

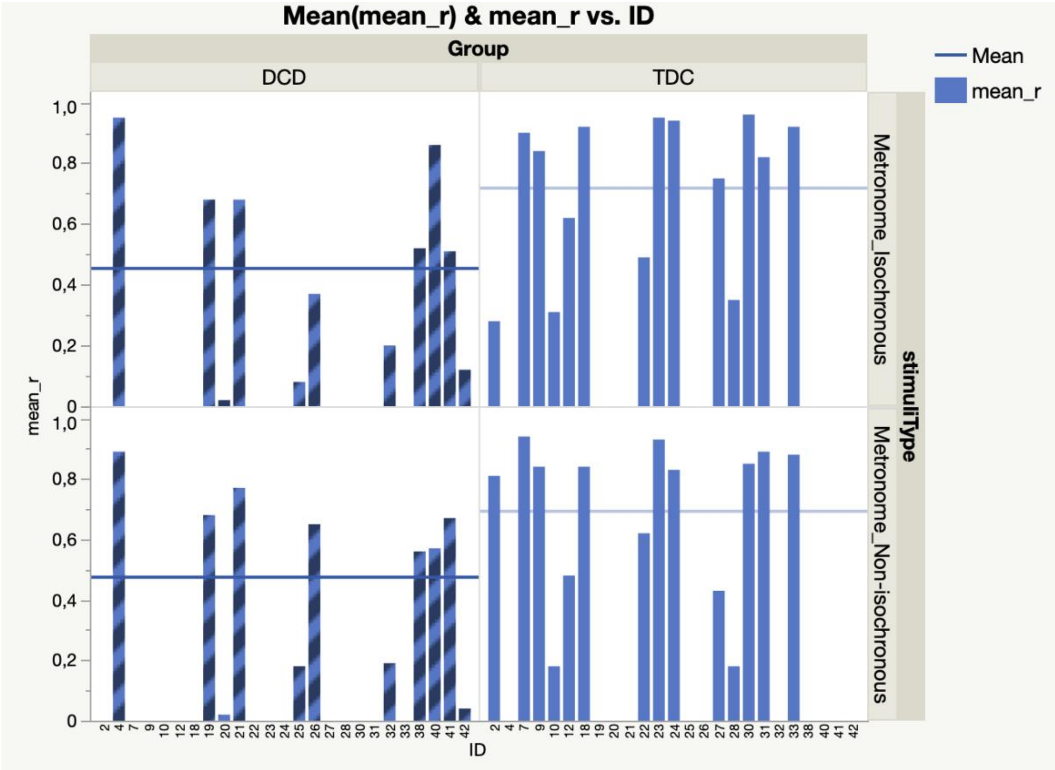


Figure 2. Visual representation of the auditory motor coupling variability (RVL) for both groups in the +10% condition

4. Auditory motor coupling in -10% condition

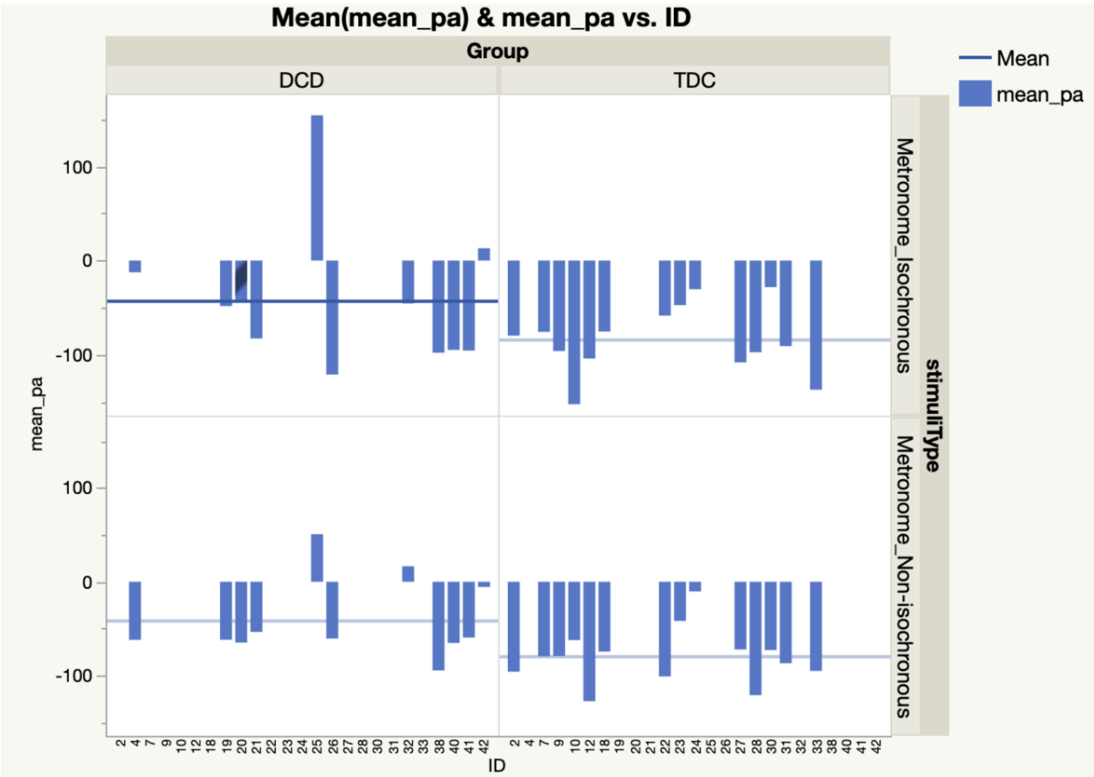


Figure 1. Visual representation of the auditory motor coupling ability (RPA) for both groups in the -10% condition

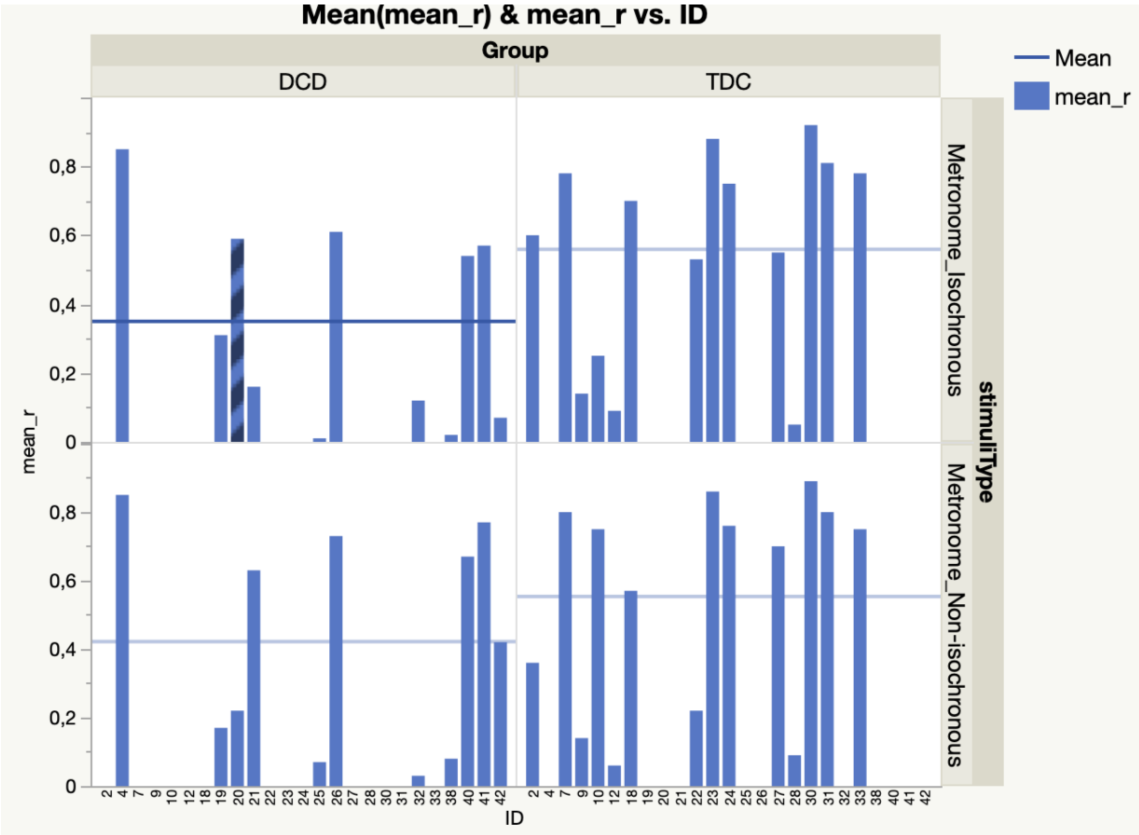


Figure 2. Visual representation of variability in auditory motor coupling (RVL) in both groups for the -10% condition

Appendix C. Statistical output of the power calculation

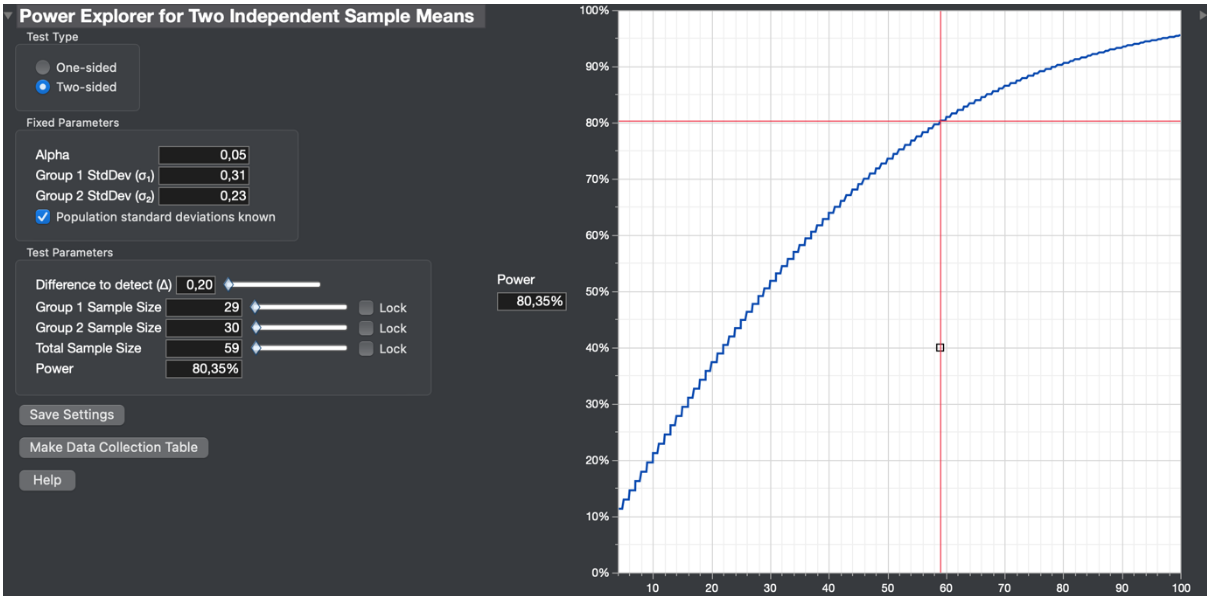


Figure 1. Sample size calculation for 80% power

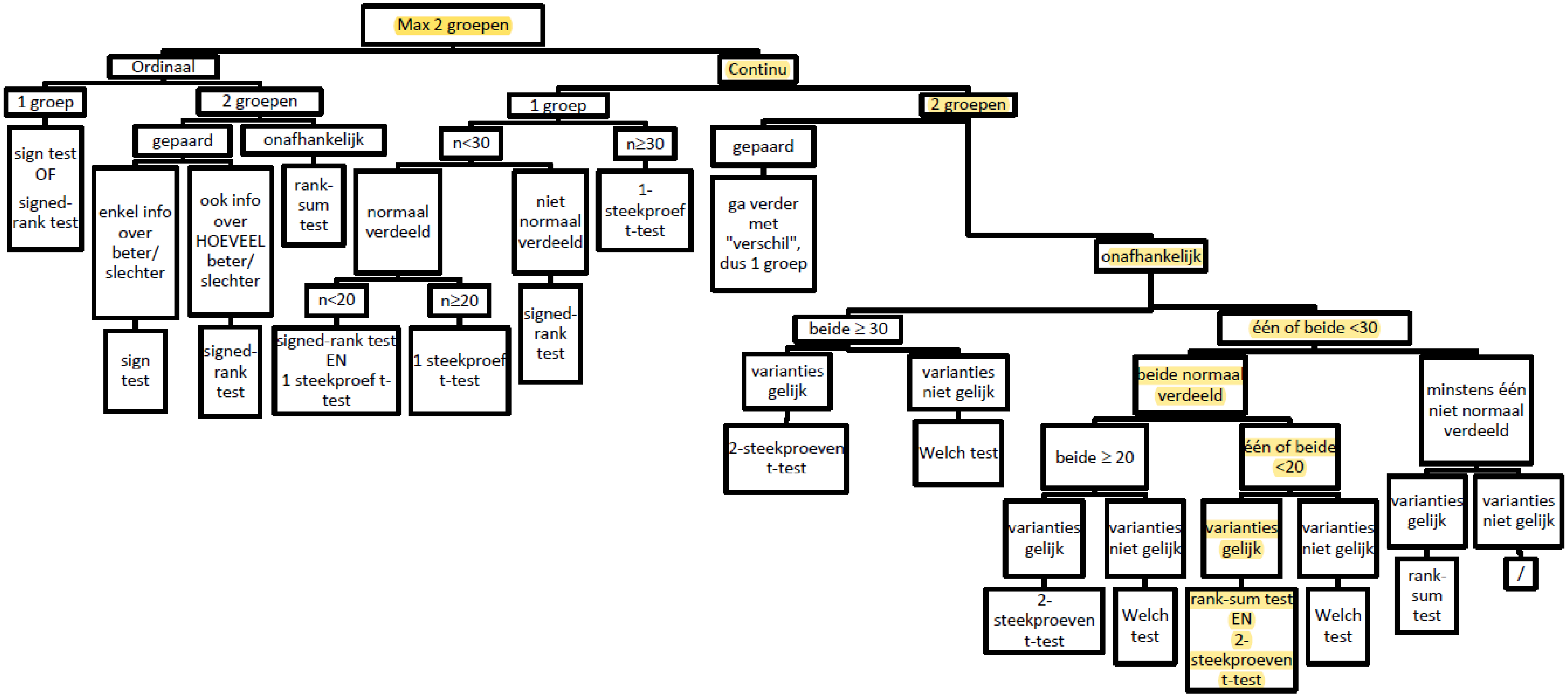
Table 1

Jmp Output for power calculation

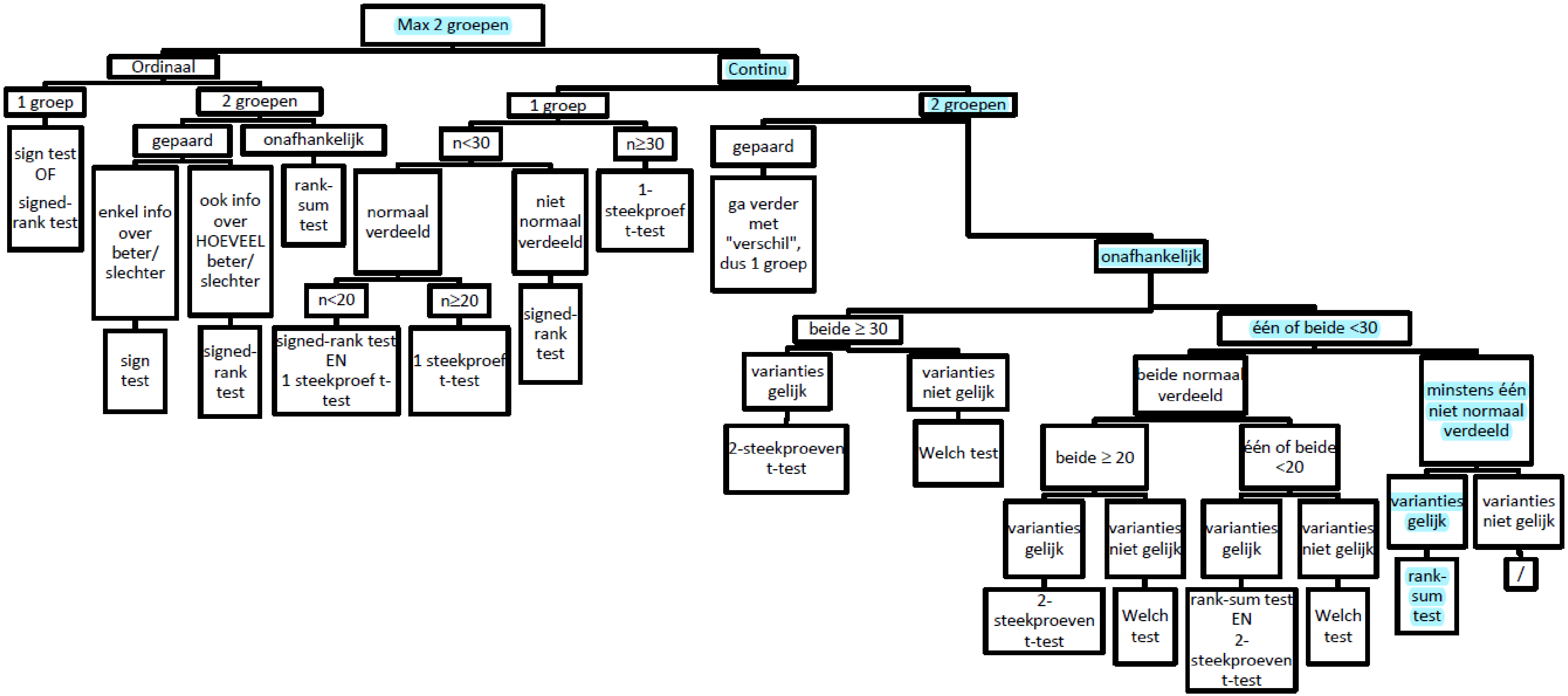
Jmp Output Oneway Analysis									
	Power Details – Test Group – Power	α	σ	δ	Number	Power	AdjPower	LowerCL	UpperCL
Rhythm perception tasks: total MBEMA score		0,0500	15,08319	0,870289	50	0,0685	0,0500	0,0500	0,6591
Auditory motor coupling tasks	**1. Non-isochronous metronome condition**	0,0500	0,281404	0,077907	25	0,2638	0,1319	0,0500	0,9108
	2. Isochronous metronome condition	0,0500	0,27775	0,133831	25	0,6360	0,5107	0,0623	0,9899

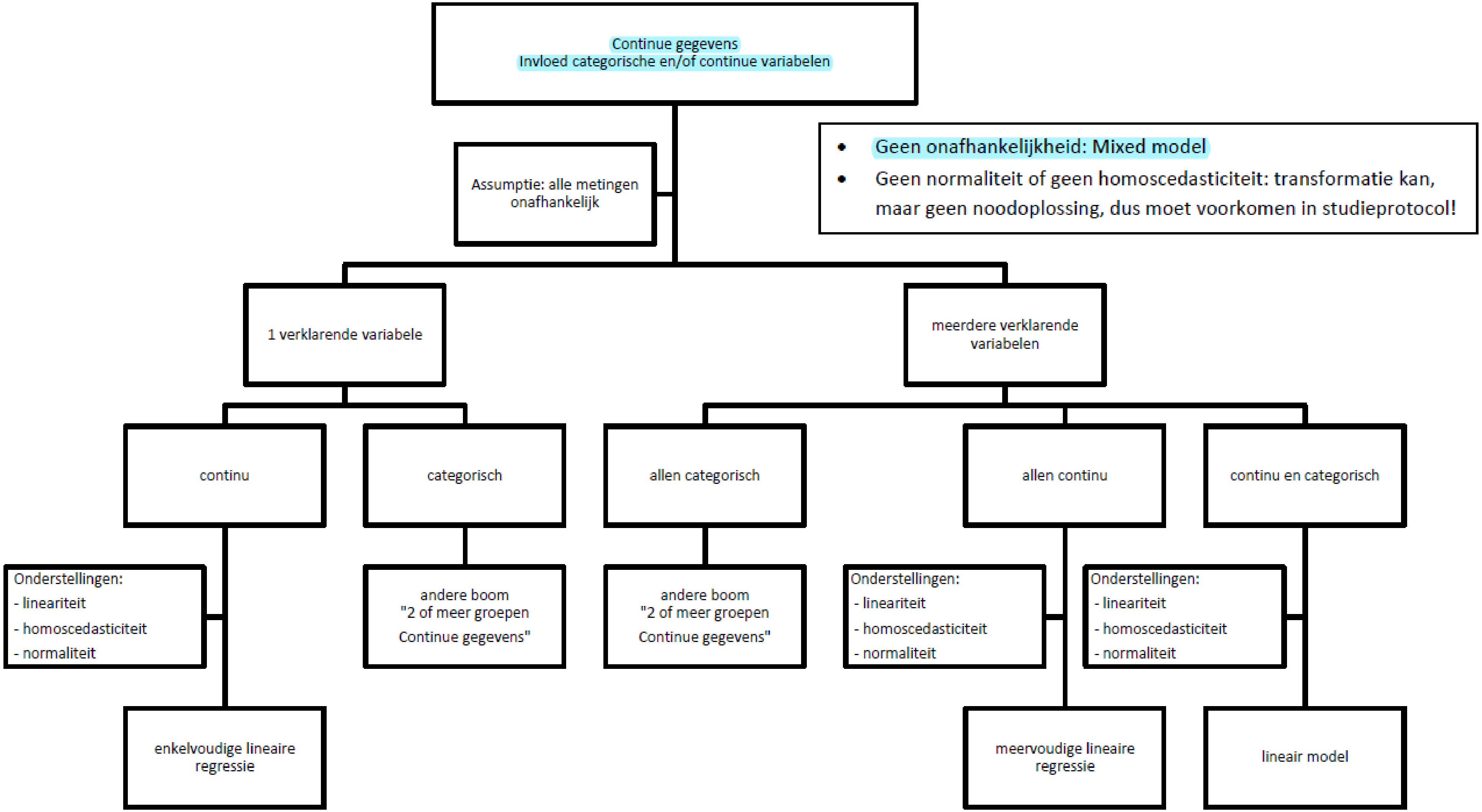
Appendix D. Decision tree of the statistical analysis

1. Rhythm perception

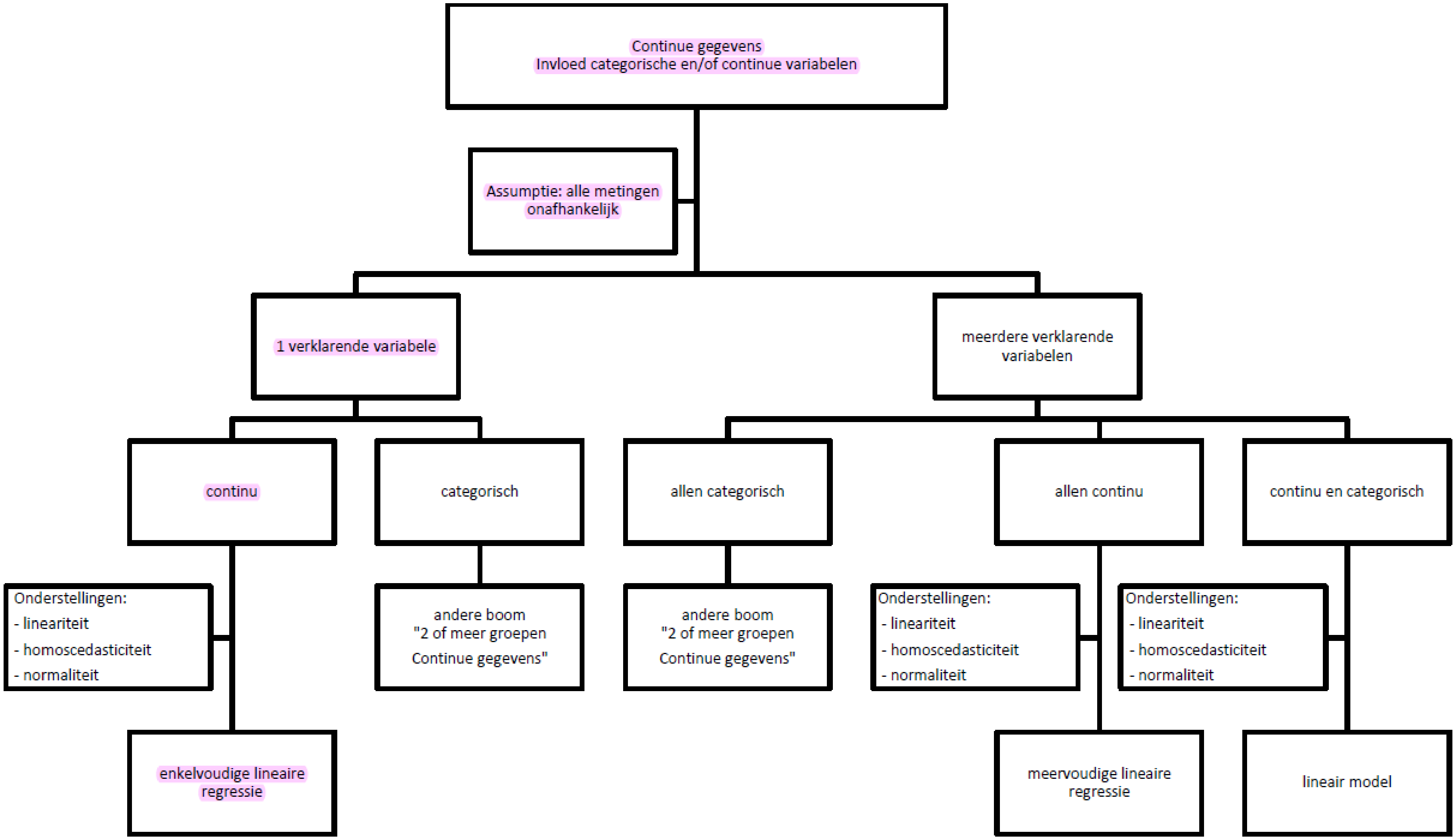


2. Auditory motor coupling

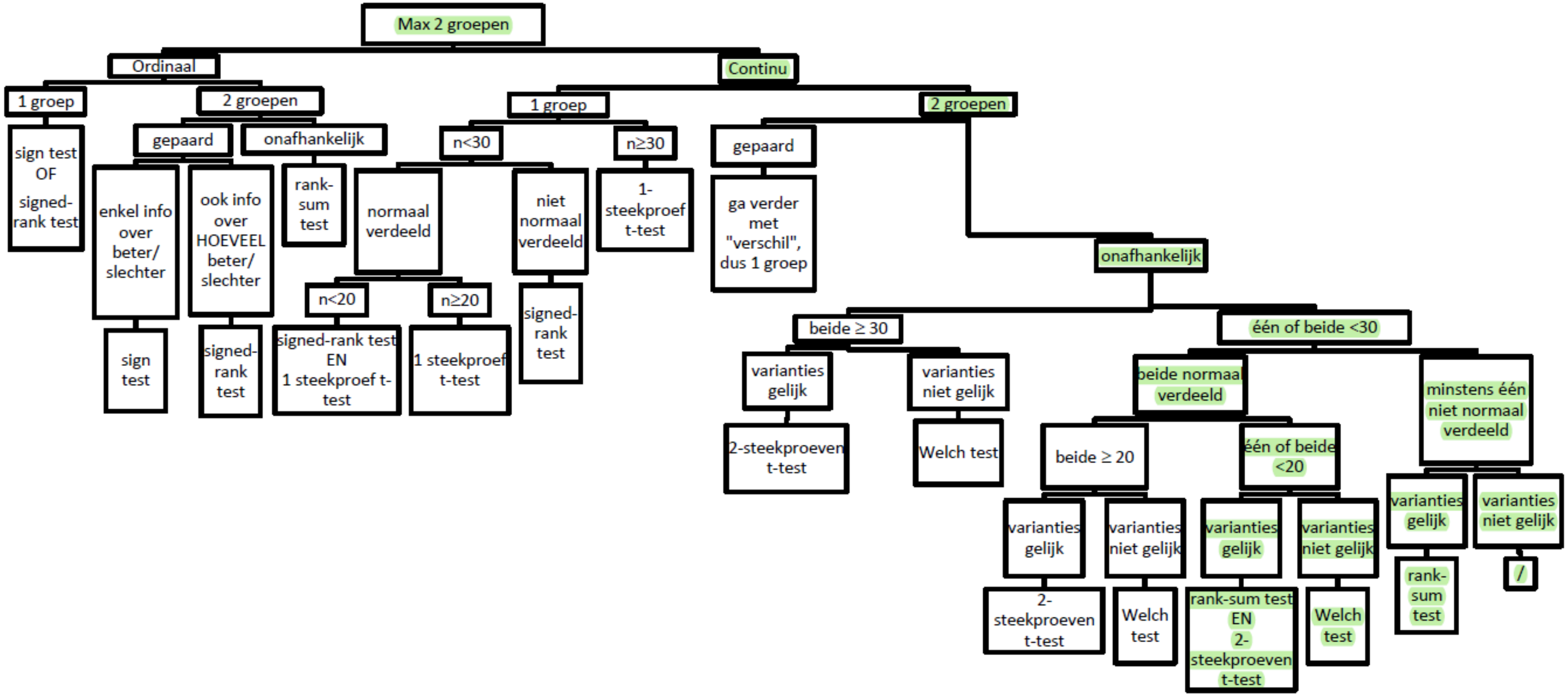


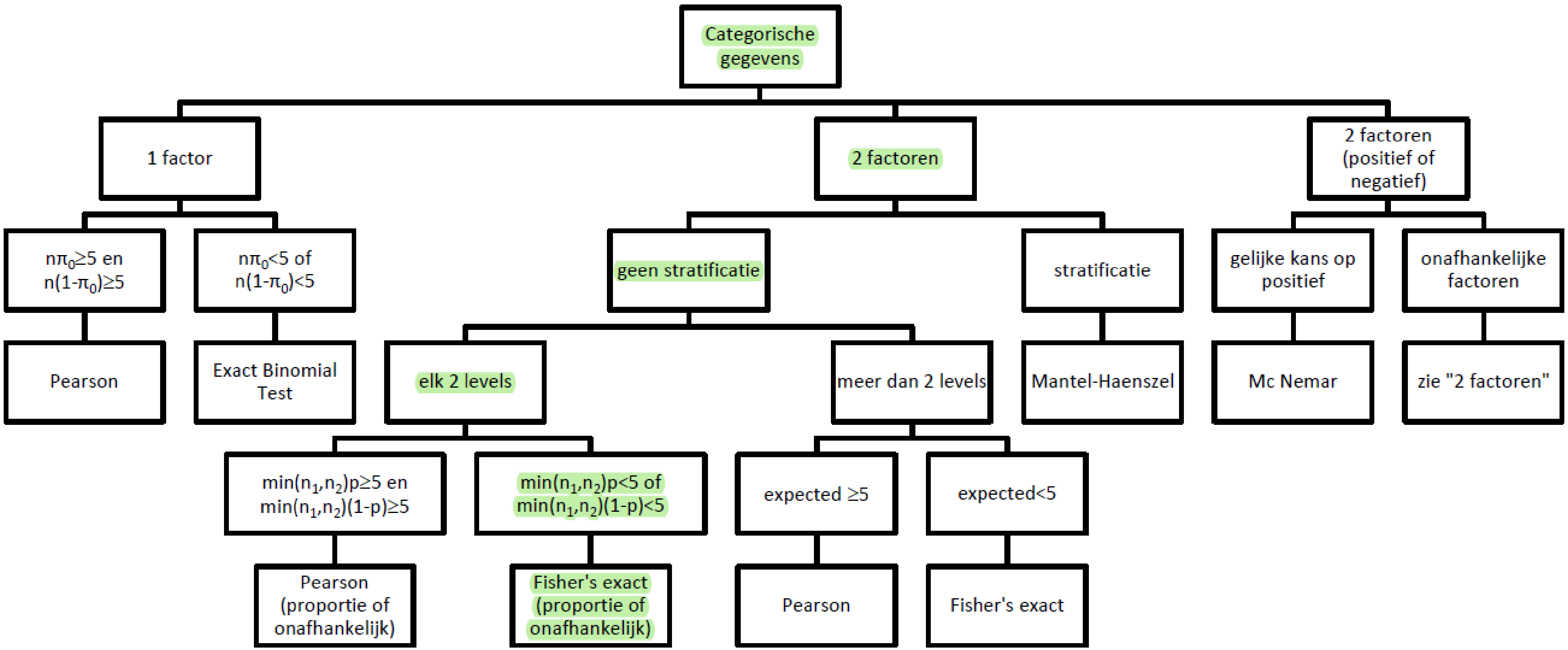

Continue gegevens
Invloed categorische en/of continue variabelen
Assumptie: alle metingen onafhankelijk
• Geen onafhankelijkheid: Mixed model
• Geen normaliteit of geen homoscedasticiteit: transformatie kan, maar geen noodoplossing, dus moet voorkomen in studieprotocol!
1 verklarende variabele
meerdere verklarende variabelen
continu
categorisch
allen categorisch
allen continu
continu en categorisch
Onderstellingen:
- lineariteit
- homoscedasticiteit
- normaliteit
andere boom
"2 of meer groepen
Continue gegevens"
andere boom
"2 of meer groepen
Continue gegevens"
Onderstellingen:
- lineariteit
- homoscedasticiteit
- normaliteit
Onderstellingen:
- lineariteit
- homoscedasticiteit
- normaliteit
enkelvoudige lineaire regressie
meervoudige lineaire regressie
lineair model

3. Link between rhythm perception and auditory motor coupling



4. Anthropometric data





Categorische gegevens
1 factor
2 factoren
2 factoren (positief of negatief)
nπ0≥5 en n(1-π0)≥5
nπ0<5 of n(1-π0)<5
geen stratificatie
stratificatie
gelijke kans op positief
onafhankelijke factoren
Pearson
Exact Binomial Test
elk 2 levels
meer dan 2 levels
Mantel-Haenszel
Mc Nemar
zie "2 factoren"
min(n1,n2)p≥5 en min(n1,n2)(1-p)≥5
min(n1,n2)p<5 of min(n1,n2)(1-p)<5
expected ≥5
expected<5
Pearson (proportie of onafhankelijk)
Fisher's exact (proportie of onafhankelijk)
Pearson
Fisher's exact

Appendix E. Approval from Prof. Dr. Eugene Rameckers for defending the thesis

Eugene RAMECKERS
aan mij, Janique, Mieke

Dag beiden

hierbij getekende formulieren.

akkoord voor de verdediging

ik zal weg dat het de jaargang vorig jaar was

check even of dit akkoord is

gr eugene
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KNOWLEDGE IN ACTION

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Faculty/School: ***Rehabilitation Sciences***

Stamnummer + naam: **1747198 Vos Annelise**
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Opleiding/*Programme*: **2 ma revalid. & kine musc.**

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O behouden - *keep*

O wijzigen - *change to*:

UHvoorlev5 29/05/2022

PS: Developmental Coordination Disorder in capital

/:

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Date and signature supervisor(s)

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PS. Developmental Coordination Disorder in capital DCD

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In tegenstelling tot het niet-bindend advies van de promotor(en) wenst de student de bovenvermelde masterproef in de bovenvermelde periode/*In contrast to the non-binding advice put forward by the supervisor(s), the student wishes:*

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Date and signature student(s)

29-5-2022

Datum en handtekening promotor(en)
Date and signature supervisor(s)

28/05/2022

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Verklaring op Eer

Ondergetekende, student aan de Universiteit Hasselt (UHasselt), faculteit Revalidatiewetenschappen aanvaardt de volgende voorwaarden en bepalingen van deze verklaring:

1. Ik ben ingeschreven als student aan de UHasselt in de opleiding Revalidatiewetenschappen en kinesitherapie, waarbij ik de kans krijg om in het kader van mijn opleiding mee te werken aan onderzoek van de faculteit Revalidatiewetenschappen aan de UHasselt. Dit onderzoek wordt beleid door Prof. Dr. Eugene Rameckers en dra. Mieke Goetschalckx en kadert binnen: het opleidingsonderdeel Wetenschappelijke stage/ Masterproef deel 2. Ik zal in het kader van dit onderzoek creaties, schetsen, ontwerpen, prototypes en/of onderzoeksresultaten tot stand brengen in het domein van Pediatrische revalidatie (hierna: "De Onderzoeksresultaten").

2. Bij de creatie van De Onderzoeksresultaten doe ik beroep op de achtergrondkennis, vertrouwelijke informatie[1], universitaire middelen en faciliteiten van UHasselt (hierna: de "Expertise").

3. Ik zal de Expertise, met inbegrip van vertrouwelijke informatie, uitsluitend aanwenden voor het uitvoeren van hogergenoemd onderzoek binnen UHasselt. Ik zal hierbij steeds de toepasselijke regelgeving, in het bijzonder de Algemene Verordening Gegevensbescherming (EU 2016-679), in acht nemen.

4. Ik zal de Expertise (i) voor geen enkele andere doelstelling gebruiken, en (ii) niet zonder voorafgaande schriftelijke toestemming van UHasselt op directe of indirecte wijze publiek maken.

5. Aangezien ik in het kader van mijn onderzoek beroep doe op de Expertise van de UHasselt, draag ik hierbij alle bestaande en toekomstige intellectuele eigendomsrechten op De Onderzoeksresultaten over aan de UHasselt. Deze overdracht omvat alle vormen van intellectuele eigendomsrechten, zoals onder meer – zonder daartoe beperkt te zijn – het auteursrecht, octrooirecht, merkenrecht, modellenrecht en knowhow. De overdracht geschiedt in de meest volledige omvang, voor de gehele wereld en voor de gehele beschermingsduur van de betrokken rechten.

6. In zoverre De Onderzoeksresultaten auteursrechtelijk beschermd zijn, omvat bovenstaande overdracht onder meer de volgende exploitatiewijzen, en dit steeds voor de hele beschermingsduur, voor de gehele wereld en zonder vergoeding:

   - het recht om De Onderzoeksresultaten vast te (laten) leggen door alle technieken en op alle dragers;
   - het recht om De Onderzoeksresultaten geheel of gedeeltelijk te (laten) reproduceren, openbaar te (laten) maken, uit te (laten) geven, te (laten) exploiteren en te (laten) verspreiden in eender welke vorm, in een onbeperkt aantal exemplaren;

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[1] Vertrouwelijke informatie betekent alle informatie en data door de UHasselt meegedeeld aan de student voor de uitvoering van deze overeenkomst, inclusief alle persoonsgegevens in de zin van de Algemene Verordening Gegevensbescherming (EU 2016/679), met uitzondering van de informatie die (a) reeds algemeen bekend is; (b) reeds in het bezit was van de student voor de mededeling ervan door de UHasselt; (c) de student verkregen heeft van een derde zonder enige geheimhoudingsplicht; (d) de student onafhankelijk heeft ontwikkeld zonder gebruik te maken van de vertrouwelijke informatie van de UHasselt; (e) wettelijk of als gevolg van een rechterlijke beslissing moet worden bekendgemaakt, op voorwaarde dat de student de UHasselt hiervan schriftelijk en zo snel mogelijk op de hoogte brengt.

- het recht om De Onderzoeksresultaten te (laten) verspreiden en mee te (laten) delen aan het publiek door alle technieken met inbegrip van de kabel, de satelliet, het internet en alle vormen van computernetwerken;
- het recht De Onderzoeksresultaten geheel of gedeeltelijk te (laten) bewerken of te (laten) vertalen en het (laten) reproduceren van die bewerkingen of vertalingen;
- het recht De Onderzoeksresultaten te (laten) bewerken of (laten) wijzigen, onder meer door het reproduceren van bepaalde elementen door alle technieken en/of door het wijzigen van bepaalde parameters (zoals de kleuren en de afmetingen).

De overdracht van rechten voor deze exploitatiewijzen heeft ook betrekking op toekomstige onderzoeksresultaten tot stand gekomen tijdens het onderzoek aan UHasselt, eveneens voor de hele beschermingsduur, voor de gehele wereld en zonder vergoeding.

Ik behoud daarbij steeds het recht op naamvermelding als (mede)auteur van de betreffende Onderzoeksresultaten.

7. Ik zal alle onderzoeksdata, ideeën en uitvoeringen neerschrijven in een "laboratory notebook" en deze gegevens niet vrijgeven, tenzij met uitdrukkelijke toestemming van mijn UHasseltbegeleider Prof. Dr. Eugene Rameckers en dra. Mieke Goetschalckx.

8. Na de eindevaluatie van mijn onderzoek aan de UHasselt zal ik alle verkregen vertrouwelijke informatie, materialen, en kopieën daarvan, die nog in mijn bezit zouden zijn, aan UHasselt terugbezorgen.

Gelezen voor akkoord en goedgekeurd,

Naam: Van Anneliese

Adres: Schaffensesteenweg 95, 3583 Paal-Beringen

Geboortedatum en –plaats : Heusden-Zolder, 25/06/1999

Datum: 30 mei 2022

Handtekening:

Verklaring op Eer

Ondergetekende, student aan de Universiteit Hasselt (UHasselt), faculteit Revalidatiewetenschappen aanvaardt de volgende voorwaarden en bepalingen van deze verklaring:

1. Ik ben ingeschreven als student aan de UHasselt in de opleiding Revalidatiewetenschappen en kinesitherapie, waarbij ik de kans krijg om in het kader van mijn opleiding mee te werken aan onderzoek van de faculteit Revalidatiewetenschappen aan de UHasselt. Dit onderzoek wordt beleid door Prof. Dr. Eugene Rameckers en dra. Mieke Goetschalckx en kadert binnen: het opleidingsonderdeel Wetenschappelijke stage/ Masterproef deel 2. Ik zal in het kader van dit onderzoek creaties, schetsen, ontwerpen, prototypes en/of onderzoeksresultaten tot stand brengen in het domein van Pediatrische revalidatie (hierna: "De Onderzoeksresultaten").

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3. Ik zal de Expertise, met inbegrip van vertrouwelijke informatie, uitsluitend aanwenden voor het uitvoeren van hogergenoemd onderzoek binnen UHasselt. Ik zal hierbij steeds de toepasselijke regelgeving, in het bijzonder de Algemene Verordening Gegevensbescherming (EU 2016-679), in acht nemen.

4. Ik zal de Expertise (i) voor geen enkele andere doelstelling gebruiken, en (ii) niet zonder voorafgaande schriftelijke toestemming van UHasselt op directe of indirecte wijze publiek maken.

5. Aangezien ik in het kader van mijn onderzoek beroep doe op de Expertise van de UHasselt, draag ik hierbij alle bestaande en toekomstige intellectuele eigendomsrechten op De Onderzoeksresultaten over aan de UHasselt. Deze overdracht omvat alle vormen van intellectuele eigendomsrechten, zoals onder meer – zonder daartoe beperkt te zijn – het auteursrecht, octrooirecht, merkenrecht, modellenrecht en knowhow. De overdracht geschiedt in de meest volledige omvang, voor de gehele wereld en voor de gehele beschermingsduur van de betrokken rechten.

6. In zoverre De Onderzoeksresultaten auteursrechtelijk beschermd zijn, omvat bovenstaande overdracht onder meer de volgende exploitatiewijzen, en dit steeds voor de hele beschermingsduur, voor de gehele wereld en zonder vergoeding:

   - het recht om De Onderzoeksresultaten vast te (laten) leggen door alle technieken en op alle dragers;
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[1] Vertrouwelijke informatie betekent alle informatie en data door de UHasselt meegedeeld aan de student voor de uitvoering van deze overeenkomst, inclusief alle persoonsgegevens in de zin van de Algemene Verordening Gegevensbescherming (EU 2016/679), met uitzondering van de informatie die (a) reeds algemeen bekend is; (b) reeds in het bezit was van de student voor de mededeling ervan door de UHasselt; (c) de student verkregen heeft van een derde zonder enige geheimhoudingsplicht; (d) de student onafhankelijk heeft ontwikkeld zonder gebruik te maken van de vertrouwelijke informatie van de UHasselt; (e) wettelijk of als gevolg van een rechterlijke beslissing moet worden bekendgemaakt, op voorwaarde dat de student de UHasselt hiervan schriftelijk en zo snel mogelijk op de hoogte brengt.

- het recht om De Onderzoeksresultaten te (laten) verspreiden en mee te (laten) delen aan het publiek door alle technieken met inbegrip van de kabel, de satelliet, het internet en alle vormen van computernetwerken;
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De overdracht van rechten voor deze exploitatiewijzen heeft ook betrekking op toekomstige onderzoeksresultaten tot stand gekomen tijdens het onderzoek aan UHasselt, eveneens voor de hele beschermingsduur, voor de gehele wereld en zonder vergoeding.

Ik behoud daarbij steeds het recht op naamvermelding als (mede)auteur van de betreffende Onderzoeksresultaten.

7. Ik zal alle onderzoeksdata, ideeën en uitvoeringen neerschrijven in een "laboratory notebook" en deze gegevens niet vrijgeven, tenzij met uitdrukkelijke toestemming van mijn UHasseltbegeleider Prof. Dr. Eugene Rameckers en dra. Mieke Goetschalckx.

8. Na de eindevaluatie van mijn onderzoek aan de UHasselt zal ik alle verkregen vertrouwelijke informatie, materialen, en kopieën daarvan, die nog in mijn bezit zouden zijn, aan UHasselt terugbezorgen.

Gelezen voor akkoord en goedgekeurd,

Naam: Janique Roufs

Adres: Leon Biessenstraat 48, 6418TL Heerlen, Nederland

Geboortedatum en –plaats : 03-02-1999 te Heerlen

Datum: 30-05-2022

Handtekening:

www.uhasselt.be
Campus Hasselt | Martelarenlaan 42 | BE-3500 Hasselt
Campus Diepenbeek | Agoralaan gebouw D | BE-3590 Diepenbeek
T + 32(0)11 26 81 11 | E-mail: info@uhasselt.be

UHASSELT
KNOWLEDGE IN ACTION

INVENTARISATIEFORMULIER WETENSCHAPPELIJKE STAGE DEEL 2

DATUM	INHOUD OVERLEG	HANDTEKENINGEN
05-07-2021	Overlopen van de gebruikte testen tijdens MP, planning van testings en uitwerking MP2	Promotor: Begeleider: dra. Mieke Goetschalckx Student(e): Janique Roufs Student(e): Annelise Vos
20-01-2022	Basisschool in Opgrimbie was geïnteresseerd voor de testings, uitleg aan Mieke wat de verwachtingen waren van de school en of we deze konden waarmaken.	Promotor: Begeleider: dra. Mieke Goetschalckx Student(e): Janique Roufs Student(e):
31-01-2022	Naar aanleiding van geïnteresseerde school voor de testings, was dit een bespreking van de praktische informatie voor deze testafname.	Promotor: Begeleider: dra. Mieke Goetschalckx Student(e): Janique Roufs Student(e):
04-02-2022	Overlopen van planning uitwerking MP2, intro en methode, onderzoeksvragen gelinkt aan de hypothese, planning van data-analyse.	Promotor: Begeleider: dra. Mieke Goetschalckx Student(e): Janique Roufs Student(e): Annelise Vos
29-04-2022	Overlopen van in- en exclusiecriteria en de geïncludeerde en geëxcludeerde proefpersonen. Ruwe data bespreken.	Promotor: Begeleider: dra. Mieke Goetschalckx Student(e): Janique Roufs Student(e): Annelise Vos
10-05-2022	Helpen met onderzoeken of de data normaal verdeeld was tijdens de statistische analyse.	Promotor: Begeleider: dra. Mieke Goetschalckx Student(e): Janique Roufs Student(e): Annelise Vos
16-05-2022	Overlopen van uitgewerkte statistiek en of dit de juiste statistische analyse zou zijn.	Promotor: Begeleider: dra. Mieke Goetschalckx Student(e): Janique Roufs Student(e): Annelise Vos
/	/	Promotor: Copromotor/Begeleider: Student(e): Student(e):
/	/	Promotor: Copromotor/Begeleider: Student(e): Student(e):
/	/	Promotor: Copromotor/Begeleider: Student(e): Student(e):

In te vullen door de promotor(en) en eventuele copromotor aan het einde van MP2:

Naam Student(e): Vos Annelise .... Datum:.....................................

Titel Masterproef: Auditory-motor coupling and rhythm perception in children with Developmental Coordination Disorder compared to typically developing children: a case-controlled study

1) Geef aan in hoeverre de student(e) onderstaande competenties zelfstandig uitvoerde:
   - NVT: De student(e) leverde hierin geen bijdrage, aangezien hij/zij in een reeds lopende studie meewerkte.
   - 1: De student(e) was niet zelfstandig en sterk afhankelijk van medestudent(e) of promotor en teamleden bij de uitwerking en uitvoering.
   - 2: De student(e) had veel hulp en ondersteuning nodig bij de uitwerking en uitvoering.
   - 3: De student(e) was redelijk zelfstandig bij de uitwerking en uitvoering
   - 4: De student(e) had weinig tot geringe hulp nodig bij de uitwerking en uitvoering.
   - 5: De student(e) werkte zeer zelfstandig en had slechts zeer sporadisch hulp en bijsturing nodig van de promotor of zijn team bij de uitwerking en uitvoering.

Competenties	NVT	1	2	3	4	5
Opstelling onderzoeksvraag	O	O	O	O	O	O
Methodologische uitwerking	O	O	O	O	O	O
Data acquisitie	O	O	O	O	O	O
Data management	O	O	O	O	O	O
Dataverwerking/Statistiek	O	O	O	O	O	O
Rapportage	O	O	O	O	O	O

2) <u>Niet-bindend advies:</u> Student(e) krijgt toelating/geen toelating (schrappen wat niet past) om bovenvermelde Wetenschappelijke stage/masterproef deel 2 te verdedigen in bovenvermelde periode. Deze eventuele toelating houdt geen garantie in dat de student geslaagd is voor dit opleidingsonderdeel.

3) Deze wetenschappelijke stage/masterproef deel 2 mag wel/niet (schrappen wat niet past) openbaar verdedigd worden.

4) Deze wetenschappelijke stage/masterproef deel 2 mag wel/niet (schrappen wat niet past) opgenomen worden in de bibliotheek en docserver van de UHasselt.

Datum en handtekening Student(e)
6-06-2022

Datum en handtekening promotor(en)

Datum en handtekening Co-promotor(en)

www.uhasselt.be
Campus Hasselt | Martelarenlaan 42 | BE-3500 Hasselt
Campus Diepenbeek | Agoralaan gebouw D | BE-3590 Diepenbeek
T + 32(0)11 26 81 11 | E-mail: info@uhasselt.be

UHASSELT
KNOWLEDGE IN ACTION

INVENTARISATIEFORMULIER WETENSCHAPPELIJKE STAGE DEEL 2

DATUM	INHOUD OVERLEG	HANDTEKENINGEN
05-07-2021	Overlopen van de gebruikte testen tijdens MP, planning van testings en uitwerking MP2	Promotor: Begeleider: dra. Mieke Goetschalckx Student(e): Janique Roufs Student(e): Annelise Vos
20-01-2022	Basisschool in Opgrimbie was geïnteresseerd voor de testings, uitleg aan Mieke wat de verwachtingen waren van de school en of we deze konden waarmaken	Promotor: Begeleider: dra. Mieke Goetschalckx Student(e): Janique Roufs Student(e):
31-01-2022	Naar aanleiding van geïnteresseerde school voor de testings, was dit een bespreking van de praktische informatie voor deze testafname.	Promotor: Begeleider: dra. Mieke Goetschalckx Student(e): Janique Roufs Student(e):
04-02-2022	Overlopen van planning uitwerking MP2, intro en methode, onderzoeksvragen gelinkt aan de hypothese, planning van data-analyse.	Promotor: Begeleider: dra. Mieke Goetschalckx Student(e): Janique Roufs Student(e): Annelise Vos
29-04-2022	Overlopen van in- en exclusiecriteria en de geincludeerde en geexcludeerde proefpersonen. Ruwe data bespreken.	Promotor: Begeleider: dra. Mieke Goetschalckx Student(e): Janique Roufs Student(e): Annelise Vos
10-05-2022	Helpen met onderzoeken of de data normaal verdeeld was tijdens de statistische analyse.	Promotor: Begeleider: dra. Mieke Goetschalckx Student(e): Janique Roufs Student(e): Annelise Vos
16-05-2022	Overlopen van uitgewerkte statistiek en of dit de juiste statistische analyse zou zijn.	Promotor: Begeleider: dra. Mieke Goetschalckx Student(e): Janique Roufs Student(e): Annelise Vos
		Promotor: Copromotor/Begeleider: Student(e): Student(e):
		Promotor: Copromotor/Begeleider: Student(e): Student(e):
		Promotor: Copromotor/Begeleider: Student(e): Student(e):

In te vullen door de promotor(en) en eventuele copromotor aan het einde van MP2:

Naam Student(e): Roufs Janique ………………………………………… Datum:…………………………….

Titel Masterproef: Auditory-motor coupling and rhythm perception in children with Developmental Coordination Disorder compared to typically developing children: a case-controlled study

1) Geef aan in hoeverre de student(e) onderstaande competenties zelfstandig uitvoerde:
   - NVT: De student(e) leverde hierin geen bijdrage, aangezien hij/zij in een reeds lopende studie meewerkte.
   - 1: De student(e) was niet zelfstandig en sterk afhankelijk van medestudent(e) of promotor en teamleden bij de uitwerking en uitvoering.
   - 2: De student(e) had veel hulp en ondersteuning nodig bij de uitwerking en uitvoering.
   - 3: De student(e) was redelijk zelfstandig bij de uitwerking en uitvoering
   - 4: De student(e) had weinig tot geringe hulp nodig bij de uitwerking en uitvoering.
   - 5: De student(e) werkte zeer zelfstandig en had slechts zeer sporadisch hulp en bijsturing nodig van de promotor of zijn team bij de uitwerking en uitvoering.

Competenties	NVT	1	2	3	4	5
Opstelling onderzoeksvraag	O	O	O	O	O	O
Methodologische uitwerking	O	O	O	O	O	O
Data acquisitie	O	O	O	O	O	O
Data management	O	O	O	O	O	O
Dataverwerking/Statistiek	O	O	O	O	O	O
Rapportage	O	O	O	O	O	O

2) <u>Niet-bindend advies:</u> Student(e) krijgt toelating/geen toelating (schrappen wat niet past) om bovenvermelde Wetenschappelijke stage/masterproef deel 2 te verdedigen in bovenvermelde periode. Deze eventuele toelating houdt geen garantie in dat de student geslaagd is voor dit opleidingsonderdeel.

3) Deze wetenschappelijke stage/masterproef deel 2 mag wel/niet (schrappen wat niet past) openbaar verdedigd worden.

4) Deze wetenschappelijke stage/masterproef deel 2 mag wel/niet (schrappen wat niet past) opgenomen worden in de bibliotheek en docserver van de UHasselt.

Datum en handtekening Student(e)	Datum en handtekening promotor(en)	Datum en handtekening Co-promotor(en)
06-06-2022