KU LEUVEN

FACULTEIT PSYCHOLOGIE EN
PEDAGOGISCHE WETENSCHAPPEN

Length Measurement Estimation Skills in Children With Developmental Coordination Disorder

Masterproef aangeboden tot het
verkrijgen van de graad van
Master of Science in de
psychologie
Door
Joke Hufkens

promotor: Prof. Dr. Bert Reynvoet
copromotor: Prof. Dr. Koen Luwel

2024

KU LEUVEN

FACULTEIT PSYCHOLOGIE EN PEDAGOGISCHE WETENSCHAPPEN

Length Measurement Estimation Skills in Children With Developmental Coordination Disorder

Masterproef aangeboden tot het
verkrijgen van de graad van
Master of Science in de
psychologie
Door
Joke Hufkens

promotor: Prof. Dr. Bert Reynvoet
copromotor: Prof. Dr. Koen Luwel

2024

Summary

This Master's thesis examines the "Length Measurement Estimation Skills in Children With Developmental Coordination Disorder (DCD)". The research was prompted by observations from practitioners with children with DCD who noted estimation difficulties. While cognitive difficulties have been recognized in children with DCD, literature regarding the measurement estimation skills in this population remains limited. Measurement estimation involves determining the size of an object without relying on conventional measurement tools, such as for length.

This thesis addresses the lack of knowledge regarding the estimation abilities of children with DCD. The study involved 45 children with DCD, aged 12 to 18 yrs. (39 males). Since this study primarily investigates which characteristics of the to be estimated objects have an influence on estimation performances of children with DCD, researchers opted not implement control groups. The research design adopted is modeled after Desli and Giakoumi's (2017) approach, containing eight distinct length estimation tasks. These tasks encompassed various characteristics of features (horizontal/vertical, short/long, with/without visual interference) and utilized two measurement unit types: standard units (in centimeters) and nonstandard units (using the size of pencils, paperclips as units).

Children with DCD exhibit big intra- and inter-individual variations in estimation performances, but these differences are largely unrelated to group factors like age and level of education. When examining children with DCD, comorbidities including AD(H)D, dyslexia, ASS, dyscalculia, epilepsy, dysorthography, and dysphasia were observed. Personal characteristics like age, education level, and comorbidity had minimal to no impact on their estimation performances. Specifically, when tasked with drawing a long line of a specific length, children with dyscalculia and DCD (without other comorbidity) showed poorer performance than those with DCD alone or in combination with ASS and/or AD(H)D, a language disorder, or multiple comorbidities. Item characteristics like object orientation, presence of visual interference and measurement unit type did not affect their estimation performances, whereas the length of said object did. Estimations for shorter items were better than those for longer items. These insights may help to develop compensating strategies for when children with DCD need to estimate.

Acknowledgements

Throughout the process of writing my Master’s thesis, I received the assistance and mentorship of several people. I would like to extend my gratitude to the following individuals and entities.

Firstly, I am thankful to Prof. Dr. Bert Reynvoet for his invaluable time and patience in guiding my thesis process. His support and advice were instrumental whenever I required assistance or direction.
Additionally, I express my sincere appreciation for Prof. Dr. Koen Luwel for his expertise and guidance in navigating the extensive literature and knowledge pertaining to estimation.

Furthermore, I would like to thank Secundair Onderwijs Dominiek Savio in Hooglede-Gits for providing the subject matter for my Master’s thesis, which deepened my understanding of Developmental Coordination Disorder. To all the employees of Secundair Onderwijs Dominiek Savio, I would like to express my gratitude for their assistance during my research process. Their insights and support were essential to the development of my research design, and their assistance in participant recruitment and research administration was invaluable. Particularly, I would like to express my gratitude to Ilse Tydgat for facilitating communication between the institution and myself. Her efforts ensured seamless communication and her contributions were invaluable. Also special thanks to her colleague, Ine Van Elslander, for organizing and engaging an informative guided tour at Secundair Onderwijs Dominiek Savio.

Contribution and Approach

Writing my Master’s thesis has been an enlightening journey. Initially, I studied literature on Developmental Coordination Disorder provided by Prof. Dr. Bert Reynvoet, which served as a solid foundation for my research. Subsequently, Prof. Dr. Koen Luwel also offered valuable literature on estimation, broadening my understanding. From there, I independently explored additional literature. The development of the research design was my responsibility along with processing the findings.

Secundair Onderwijs Dominiek Savio assisted in recruiting participants and facilitating the process of data gathering. Due to distance constraints, I could not conduct all measurements myself. They also provided guidance and support.

Ensuring broader accessibility within the scientific community, the paper was written in English. Artificial Intelligence has been used as a language check where it was thought to be beneficial for clarity of the paper.

Table of Contents

List of Tables

List of Figures

Introduction

Developmental Coordination Disorder (DCD) manifests diversely (Visser, 2003), characterized by impaired acquisition and execution of movement skills (Smits-Engelsman et al., 2017). Common aspects include fine motor skill difficulties, gross motor skill challenges, or a combination thereof (Visser, 2003). Asonitou et al. (2012) found that children with DCD exhibit significantly lower performance levels in both motor and cognitive tasks, with significant correlations between motor abilities and cognitive processes. Concurrently, significant correlations were observed between cognitive processing and manual dexterity for both children with and without DCD (Asonitou et al., 2012). Additionally, Reynvoet et al. (2020) note that many children with DCD struggle with mathematical skills, particularly in advanced areas requiring executive functions such as inhibition, flexibility, and memory. They further highlight diminished executive functioning abilities among children with DCD (Reynvoet et al., 2020). Regarding mathematical performance particularly, Vaivre-Douret et al. (2011) demonstrated that a majority of children with DCD exhibit lower performance in mathematical activities. Specifically, Pieters et al. (2012) identified difficulties in fact-retrieval and procedural calculation. In another study, Alloway (2007) observed a diminished working memory capacity among children with DCD, potentially contributing to poorer geometry skills (Waber et al., 2021).

Measurement estimation holds great importance in this study. It entails determining values like length, weight, and volume to make a distinction with exact measurement (Hogan & Brezinski, 2003). Measurement estimation can be defined as the process of making a measurement for an object without relying on measurement instruments or tools. Estimation forms a critical facet of mathematical cognition (Siegler & Booth, 2005). Additionally, estimation skills, particularly those related to length, are commonly used in daily life (Hoth et al., 2023). Thus, this skill plays a central role in guiding us through both everyday and professional contexts. For instance, various traffic scenarios demand the ability to estimate length, such as interpreting specific signs indicating speed limits over a certain distance or when following GPS instructions. Another scenario is gift-wrapping, where accurately estimating length is essential for fully covering the present (Hoth et al., 2023).

This research paper aims to address the lack of knowledge about length estimation performances in the particular context of children with DCD. This paper explores the impact of age, level of education and possible comorbidities in children with DCD on their measurement estimation performances. Moreover, it investigates how several manipulations of the task affect estimation performances in children with DCD. Manipulations include changing the length of the items, the orientation of the object, presence of visual interference, and measurement in standard (in cm) versus nonstandard units (e.g. How many pencils fit in this object?), based on the study of Desli and Giakoumi (2017). They aimed to examine elementary school children's performance and strategies when estimating linear measurements. In our study, with children who have DCD, only performances were included.

Developmental Coordination Disorder

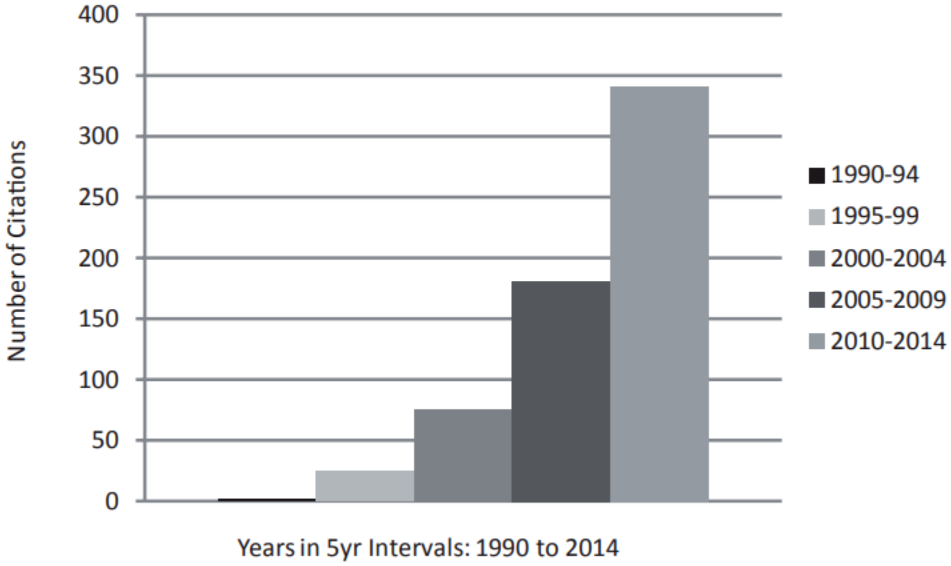
Definition and Terminology

DCD was initially introduced by the American Psychiatric Association in the DSM-III in 1987, and subsequently inlcuded in the DSM-IV and DSM-IV-TR (Vaivre-Douret et al., 2011). Children with DCD form a heterogeneous group, characterized with common traits such as clumsiness and developmental dyspraxia. Additionally, DCD is understood as an underdevelopment of certain aspects of cortical control processes that hinder the transmission of information to the body (Wilson et al., 2003). Unlike other developmental disorders such as ADHD and ASS, DCD may appear as a disparate array of conditions lacking defined signs and symptoms, or as a specific disorder (Vaivre-Douret et al., 2011). In an effort to further delineate the condition, Polatajko et al. (1995) documented a consensus meeting held in London in 1994, which led to the adoption of the term DCD to describe children facing significant motor coordination challenges. According to this consensus, DCD is a chronic and often permanent condition characterized by impaired motor performance. Furthermore, it often results in functional deficits not explained by age, intellect, or any other diagnosable neurological or psychiatric disorder. These deficits typically manifest in movement and spatiotemporal organization issues. Various features associated with DCD include decreased performance in fine and gross motor development patterns, motor performance equivalent to the individual's current age, movement quality, functional abilities in different settings (home, play and school), as well as the level of effort and/or difficulty encountered with new motor-based tasks. Indirect consequences of DCD may include poorer self-esteem, social acceptance, and coping strategies (Polatajko et al., 1995). DCD is defined as an impaired ability to learn and execute movement skills (Smits-Engelsman et al., 2017). Furthermore, individuals with DCD often struggle with acquiring and performing coordinated motor skills, resulting in difficulties with everyday activities. Boitteau et al. (2020) highlight that these challenges are key features of DCD. Individuals may exhibit pronounced clumsiness and experience (partial) delays in reaching psychomotor milestones, such as sitting, crawling, and walking. Later, this may involve dropping or bumping into objects. Examples of challenges at home include cutting food and tying shoelaces, while examples at school encompass writing and playing games (Boitteau et al., 2020).

There has been a growing focus on DCD in academic literature (Cairney & King-Dowling, 2016). This trend is evident in Figure 1, which depicts the escalating number of hits for the term "developmental coordination disorder" in PubMed. This figure shows an exponential increase. DCD has been progressively gaining attention in developmental pediatrics, pediatric neurology and psychiatry, and rehabilitation. Consequently, our understanding of DCD and the available information about it have been expanding, highlighting its relevance.

Figure 1

Number of Citations in PubMed Using the Search Term "Developmental Coordination Disorder"



Note. Number of Citations in PubMed Using the Search Term "Developmental Coordination Disorder". From *Comorbid Conditions Among Children with Autism Spectrum Disorders. Autism and Child Psychopathology Series* (p. 304), by J. Cairney & S. King-Dowling, 2016, Springer, Cham.

Classification and Diagnostics

Nowadays, the DSM-V categorizes DCD as a Neurodevelopmental Disorder, specifically under Motor Disorders (American Psychiatric Association, 2013). According to the DSM-V, the diagnosis of DCD should rely on a clinical synthesis of medical and developmental history, physical examination, reports from school or workplace, and individual assessment using psychometrically reliable and culturally appropriate standardized tests. The manifestation of impaired motor coordination skills varies depending on age. In young children with DCD, delays in reaching motor milestones such as sitting and walking may be evident, although eventually many children with DCD achieve these milestones in a later stage. Moreover, young children may also demonstrate delays in mastering skills such as descending stairs and using zippers. Additionally, even after acquiring a skill, its execution may still be clumsy, sluggish, or less accurate. Furthermore, older children and adults may display inaccuracies or slowness in motor aspects of tasks such as puzzle assembly, handwriting, typing, driving, or performing self-care activities. The DSM-V notes that DCD does not have distinct subtypes, although some individuals may primarily struggle with fine motor skills, including handwriting, or gross motor skills, (American Psychiatric Association, 2013). DCD is observed across cultures, races, and socioeconomic backgrounds, according to the DSM-V (American Psychiatric Association, 2013). The Diagnostic and Statistical Manual of Mental Disorders (5th ed.; henceforth DSM-V; American Psychiatric Association, 2013) lists alternative terms for DCD such as childhood dyspraxia, specific developmental disorder of motor function, and clumsy child syndrome.

Clinical Presentation

As per the DSM-V, delayed achievement of motor milestones could serve as initial indicators of DCD (American Psychiatric Association, 2013). DCD is typically recognized when a child encounters difficulties with tasks such as handling utensils like a knife and fork, buttoning clothes, or participating in ball games. During middle childhood, challenges arise in motor aspects of activities such as assembling puzzles, constructing models, handwriting, and engaging in ball sports. Additionally, struggles with organizing items arise when motor sequencing and coordination are required. In early adulthood, difficulties emerge in acquiring new tasks involving complex or automatic motor skills, such as driving and using tools. Moreover, individuals may face challenges in taking notes and writing quickly, possibly impacting workplace performance. The presence of comorbidities further influences demonstration, progression, and outcome. Consequences of DCD encompass reduced involvement in team play and sports, diminished self-esteem, and self-worth, emotional or behavioral issues, impaired academic performance, reduced physical fitness, and an increased risk of obesity (American Psychiatric Association, 2013).

Comorbidity

The DSM-V identifies comorbid conditions such as attention-deficit/hyperactivity disorder (ADHD), specific learning disabilities, and autism spectrum disorder (American Psychiatric Association, 2013). Additionally, it notes that the impairment due to DCD tends to increase in the presence of other comorbidities. Common comorbidities listed include speech and language disorders, specific learning disorders (particularly in reading and writing), problems of inattention (including ADHD, the most prevalent coexisting condition, occurring in approximately 50% of cases), autism spectrum disorder, disruptive and emotional behavior problems, and joint hypermobility syndrome. Furthermore, having DCD may complicate testing and this getting an adequate diagnosis (American Psychiatric Association, 2013).

Differential diagnoses

The DSM-V mentions several potential differential diagnoses, including motor impairments resulting from another medical condition, particularly visual impairment, and specific neurological disorders (such as cerebral palsy, progressive lesions of the cerebellum, and neuromuscular disorders; American Psychiatric Association, 2013). Another consideration is intellectual disability (intellectual developmental disorder), as motor abilities may be affected in line with the level of intellectual impairment. Attention-deficit/hyperactivity disorder (ADHD) is also mentioned, as individuals with ADHD may exhibit behaviors such as falling, bumping into objects, or knocking things over. Additionally, individuals with autism spectrum disorder may demonstrate disinterest in activities requiring complex coordination skills, such as ball sports, which could impact test performance and function without necessarily reflecting core motor incompetence. The DSM-V also mentions joint hypermobility syndrome, where individuals with this syndrome involving hyperextensible joints (evidenced during physical examination and often accompanied by pain complaints) may exhibit symptoms resembling those of DCD (American Psychiatric Association, 2013).

Etiology, Prognosis and Prevalence

The estimated prevalence of DCD varies depending on the definition used and the population studied (Boitteau et al., 2020). Cairney and King-Dowling (2016) note that many sources, including the DSM-V, report a prevalence of 5%, without mentioning the population studied. However, a study of 2282 Indian children aged 6 to 15 yrs. old found a prevalence rate of 0.8% (Girish et al., 2016). Sujatha et al. (2020) found an overall prevalence rate of 3.8% in Indian school children aged 8 to 16 yrs. The prevalence of suspected DCD was 12.2% in Spanish classrooms (Delgado-Lobete, 2019). Additionally, DCD symptoms were significantly associated with males. Most studies indeed indicate a predominance of males with DCD (Boitteau et al., 2020). The DSM-V also states that males are more affected than females, with a male-to-female ratio ranging from 2:1 to 7:1 (American Psychiatric Association, 2013).

As mentioned before, Polatajko et al. (1995) described in a document regarding a consensus meeting in London in 1994 that DCD is chronic and often permanent. However, the DSM-V characterizes the course of DCD as variable but generally stable, lasting at least up to one year of follow-up (American Psychiatric Association, 2013). While there may be long-term improvement, issues with coordination persist into adolescence for an estimated 50-70% of children. Furthermore, studies have shown that for certain individuals with developmental coordination impairments, the challenges persist into adulthood (Cousins & Smyth, 2003; Kirby et al., 2008).

Possible Causes and Underlying Mechanisms

There are various risk factors associated with the development of DCD, as well as prognostic factors outlined in the DSM-V, encompassing both environmental, genetic, and physiological aspects (American Psychiatric Association, 2013). Firstly, DCD is more prevalent in individuals who have been exposed to alcohol prenatally and in those born prematurely or with low birth weight, hence the environmental factors. Regarding the genetic and physiological components, research has identified impairments in underlying neurodevelopmental processes, particularly in visual-motor skills. These impairments hinder the ability to swiftly adjust motor movements as the complexity of the required actions increases. Visual-motor integration, defined as the coordination between visual information and motor programming, plays a crucial role in influencing writing skills (Brown & Rodger, 2008). Cerebellar dysfunction has been suggested as a possible factor, but the neural basis of DCD remains largely unclear according to the DSM-V (American Psychiatric Association, 2013). Due to the potential co-occurrence of ADHD, specific learning disabilities, and autism spectrum disorder in DCD, there may be a shared genetic influence (American Psychiatric Association, 2013). Wilson et al. (2017) demonstrated reduced cortical thickness in the right medial orbitofrontal cortex in individuals with DCD. Altered brain activation patterns within functional networks involving prefrontal, parietal, and cerebellar regions have also been observed in children with DCD. Additionally, imaging studies have suggested reduced white matter in sensorimotor structures and altered structural connectivity across the entire brain network in individuals with DCD. These differences compared to children without DCD may affect proactive planning and decrease the automatization of movement proficiency (Wilson et al., 2017).

Peters et al. (2013) found that children with DCD exhibit activation of multiple brain areas different from those without DCD. Moreover, they identified white matter abnormalities and severe MRI irregularities. Boitteau et al. (2016) investigated brain areas associated with DCD, finding connections to the cerebellum, basal ganglia, parietal lobe, and various regions of the frontal lobe, including the medial orbitofrontal cortex and dorsolateral prefrontal cortex.

Estimation Performances

The importance of mathematics in everyday life has become more important (Desli & Giakoumi, 2017). Siegler and Booth (2005) describe estimation as a critical facet of mathematical cognition. Everyday scenarios where estimation is crucial include selecting clothing to wear based on the weather and choosing products based on their prices, like choosing an adequate product for the best price possible. Among these practical skills, estimation has garnered considerable attention. Moreover, estimation plays a vital role in mathematical knowledge, such as estimating the time required to complete tasks or the cost of a large pizza. It is possible that estimation is used more frequently in daily life than any other mathematical process. Estimation can be defined as the process of translating between different quantitative representations, with at least one being imprecise (Siegler & Booth, 2005). These representations may be numerical or non-numerical. Numerical estimation involves estimating one or both sides of the translation using numbers, while non-numerical estimation does not involve numerical values on either side (Siegler & Booth, 2005). Sowder (1992) makes a distinction between estimating calculations, estimating quantities and estimating measurements. Number line estimation has gained attention the last 20 yrs. (Sowder, 1992). According to Siegler and Booth (2005), estimation can be classified into various types, including computational estimation, numerosity estimation, and number line estimation. Hogan and Brezinski (2003) mentioned a form of estimation known as measurement estimation. Our estimation instrument is based on the one used in the study of Desli and Giakoumi (2017).

Computational Estimation

The first form of estimation is computational estimation. This form of estimation entails solving an arithmetic problem with the aim of approximating the correct magnitude rather than obtaining an exact solution (LeFevre et al., 1993). According to Hogan and Brezinski (2003), computational estimation is the process of determining an approximate output value without excessive reliance on exact numerical values. This type of estimation involves simplifying the problem using a set of rules or procedures to arrive at an approximate answer (LeFevre et al., 1993). Computational estimation requires several understandings, including (1) aiming to produce an answer reasonably close in magnitude to the correct one, (2) recognizing the utility of approximate numbers, (3) understanding that estimation can involve multiple valid strategies and potential answers, and (4) acknowledging the significance of context in determining the adequacy of answers (LeFevre et al., 1993).

Numerosity Estimation

A different form of estimation, described by Siegler and Booth (2005), is numerosity estimation. This form of estimation involves assigning a numerical value to a collection of distinct objects, such as people at a concert or coins in a jar. Luwel et al. (2000) identified three primary strategies for numerosity estimation, which include addition, subtraction, and rough estimation, used to determine the quantity of colored blocks in square grids of various sizes. In the addition strategy, blocks (or groups of blocks) are counted and added together (Luwel et al., 2000). This strategy is also commonly referred to as exact counting (Gandini et al., 2008). Conversely, the subtraction strategy involves subtracting the number of empty squares from the total amount of squares in the grid, either estimated or calculated (Luwel et al., 2000). The third strategy is the rough estimation strategy which entails quickly but imprecisely determining the number of blocks. Siegel et al. (1982) distinguished two additional strategies for numerosity estimation: benchmark estimation and decomposition/ recomposition estimation. Benchmark estimation involves applying a known standard to estimate, such as comparing the item to be estimated to a foot ruler. If no suitable benchmark is available, a manageable fraction or multiple is used. Decomposition estimation involves breaking down the item into smaller sections to apply a benchmark, then recomposing these sections to obtain a final total (Siegel et al., 1982). Later, Gandini et al. (2008) coined more strategies such as anchoring: enumerating several dots (via counting), visually estimating the remaining dots based on the first enumeration, and then adding the enumerated result and the estimated result. Furthermore, they mention approximate counting as a strategy: perceiving several groups of different sizes and then approximately adding these groups to produce estimates. Lastly, Gandini et al. (2008) found that there are strategies which did not correspond with other categories.

Number Line Estimation

Additionally, Siegler and Booth (2005) describe a third form of estimation as number line estimation. This form of estimation involves estimating the position of a given number along an empty number line which is bounded at both sides (Siegler & Booth, 2005). This method directly reveals information about the representation of numerical magnitude. Among these tasks, another version is the ‘number to position bounded’ task employing Arabic numerals, according to Ruiz et al. (2023). Individuals are presented with a horizontal line labeled with endpoints that indicate the range of the number line. They are then shown a series of Arabic numerals and instructed to position them on the line according to their value, considering the number-to-position relationship (Ruiz et al., 2023).

Measurement Estimation

A fourth and final form of estimation discussed in this paper is measurement estimation. Achieving proficiency in measurement skills requires understanding the principles, acquiring the know-how, and recognizing the importance of fundamental measurement concepts, procedural abilities, mathematical formulae, relationships, and measurement facts (Gooya et al., 2011). It also involves having an appropriate vocabulary and a standard set of reference units for measurement estimation and evaluation.

This study will further focus on measurement estimation. This type of estimation involves determining values such as length, weight, and volume (Hogan & Brezinski, 2003). Hogan and Brezinski (2003) define measurement estimation as the process of assessing measurements for an object without utilizing measurement instruments or tools. Measurement estimation, as emphasized by Jones and Taylor (2009), holds significance as individuals across various professions consider it crucial for success in their careers. For instance, chefs rely on estimation to determine the appropriate quantity of ingredients needed for recipes.

More specifically, this research paper will focus on length estimation as this form of estimation constitutes a component of measurement estimation, as highlighted by Hogan & Brezinski (2003). Chang et al. (2011) describe length estimation as a mental process requiring the generation of an imagined measurement unit. This mental measurement unit is used for determining the length of a physical object. This unit is a mental representation of a physical object or distance. In exact length measurement individuals use instruments such as rulers or other manipulatives to get a result (Sarama et al., 2022). Joram et al. (1998) describe length estimation as mentally partitioning an object into smaller units and then enumerating these units. Another crucial aspect involves the ability to recall or construct a mental image of the unit and compare it multiple times with the object being estimated (Joram et al., 1998). Huang's study (2020) indicates that proficiency in measurement estimation improves with grade level at school. Additionally, estimations tend to be most accurate for medium-sized objects (11-50 cm), followed by small-sized objects (1-10 cm) and large-sized objects (51-100 cm). Large-sized objects were often underestimated. Pupils with superior estimation skills commonly utilize body parts and basic objects as reference points. Furthermore, combining measurement units from prior knowledge and eyeballing prove to be effective strategies.

Desli and Giakoumi (2017), of which we obtained our estimation instrument, observed that length measurement estimation performances were notably deficient among both third and fifth-grade students who had not received formal instruction in length estimation at school. In their study, fifth graders outperformed third graders only in estimating measurements using nonstandard units (like pencils or paperclips), while both age groups exhibited similar performance levels when estimating in centimeters. Moreover, proficiency in length estimation was higher when using nonstandard units. The estimation strategies predominantly relied on reference points and the iterative use of units. These findings, along with the employed strategies, suggest that young children possess some understanding of the principles underlying estimation. Their study encompasses eight length estimation tasks. Their instrument consisted of 16 items, taking into account different kind of characteristics such as the length of the object shown, the orientation in which an object is shown, the possible presence of visual interference, spatial dimensionality (two-dimensional image versus three-dimensional object) and representations of standard units of measurement (Desli & Giakoumi, 2017).

Measurement Estimation in Children With DCD

The lack of systematic investigation concerning measurement estimation in children with DCD has motivated this study. Clinicians working with children who have DCD often encounter challenges related to estimation performances. Given the limited scientific knowledge on this subject, this paper aims to gain better understanding by performing demand-driven research. Despite conducting searches on platforms such as Limo and Google Scholar using various combinations of keywords, no relevant studies were identified.

Through meetings with practitioners who work with children with DCD, valuable insights into the challenges faced by children and adolescents with DCD have been gained. These were an inspiration for this research paper. One prominent issue highlighted by these professionals is the difficulty in estimation performances observed in this population. These practitioners encountered these challenges while working with affected children and, upon finding limited existing research literature on the topic, prompted us to further investigation. As a result, research questions were formulated, centering on children with DCD aged between 12 and 18 years, utilizing a research design inspired by the methodology employed by Desli and Giakoumi (2017). This research entails various characteristics of the to be estimated objects within estimation performances. Children with DCD get presented multiple length estimation tasks concerning different characteristics of features such as visual interference, length, and orientation of task.

Method

Participants

In this research, 45 children with DCD, aged between 13 and 18 years old at enrollment, participated. They were recruited through special education need instructors of Dominiek Savio, in Hooglede, Belgium. The questionnaires were administered in Dutch, reflecting the school’s location and the predominant mother tongues of the students. All participants were attending secondary school, ranging from the first to the fifth year (see Table 1). Three children were born in 2005 (6.7%), 7 in 2006 (15.6%), 3 in 2007 (6.7%), 14 in 2008 (31.1%), 15 in 2009 (33.3%), and 3 in 2010 (6.7%). The mean age of the participants is 15.11 yrs. (*SD* = 1.39 yrs.). Throughout the remainder of this research paper, age will be discussed in years.

Table 1

Number and Percentage of Participants per Year and Grade of Secondary School

Year of Secondary School	Number of Participants	Percentage of Participants
1	6	13.3%
2	15	33.3%
3	9	20.0%
4	5	11.1%
5	7	15.6%
Unknown	3	6.7%

Note. The educational high school system in Flanders typically spans six years (Onderwijs Vlaanderen, n.d.). None of the participants were enrolled in their sixth year of secondary school. Moreover, in Flanders, two years are combined into a single grade. The first grade comprises the first and second years of secondary school, the second grade comprises the third and fourth years, and the third grade comprises the fifth and the sixth years (Onderwijs Vlaanderen, n.d.). Given the absence of participants in the sixth year, it can be inferred that the third grade includes seven children (15.6%).

Flanders initiated the modernization of its high school system in 2021, a process set to continue until 2026 (Onderwijskiezer, n.d.). General Secondary Education (ASO) is akin to d-finality, emphasizing abstract-theoretical learning (Onderwijs Vlaanderen, n.d.). Technical Secondary Education (TSO) corresponds to d- or d/a-finality. D/a-finality blends theoretical and practical elements. Meanwhile, Vocational Secondary Education (BSO) aligns with a-finality, emphasizing practical skills (Onderwijs Vlaanderen, n.d.). The first two years of high school remain either A-field or B-field (Onderwijskiezer, n.d.). A-field is pursued by students who have obtained their primary school certificate, while B-field is an option for those who have not (Vanbasisnaarsecundair, n.d.). From years three to six, students choose from the finalities or ASO, BSO, TSO, or KSO

(Onderwijs Vlaanderen, n.d.). Notably, none of the participants in this study pursued KSO. For categorizing purposes, A-stroom has been categorized as d-finality category, B-stroom as a-finality, and TSO as d/a-finality. Regarding the educational levels represented in this research, 23 children were in the d-finality (51.1%), 10 were in the d/a-finality (22.2%), and 9 were in the a-finality (20.0%). The educational backgrounds of three participants were unknown (6.7%).

In terms of the participants' gender distribution, 39 were male (86.7%) and 6 were female (13.3%)[1]. Referring to the previously mentioned male-to-female ratio can be beneficial, ranging between 2:1 and 7:1 according to the DSM-V (American Psychiatric Association, 2013).

Table 2

Comorbidities in the Participants

Comorbidity	**Number of Participants**	**Percentage of Participants**
AD(H)D	13	28.9%
Dyslexia	12	26.7%
ASS	7	15.6%
Dyscalculia	4	8.9%
Epilepsy	2	4.4%
Dysorthography	1	2.2%
Diabetes	1	2.2%
Dysphasia	1	2.2%

Note. Additionally, 28 participants experienced at least one comorbidity (64.4%). The comorbidity status of one participant remains unknown. Regarding dyslexia, 12 participants were affected (26.7%), although dyslexia was only suspected in one case without a confirmed diagnosis. Four participants had been diagnosed with ASS (8.9%), while three exhibited significant characteristics of ASS (6.7%).

---

[1] Desli and Giakoumi (2017) did not find gender differences in the estimation performances. Thus, it is not a problem that our study did not account for gender since they were mostly males.

Among the previously mentioned comorbidities (see Table 2), one adolescent is affected by epilepsy, dyslexia, ADHD, and DCD (2.2%). Another adolescent experiences ASS, diabetes, and DCD (2.2%). Additionally, one child has diagnoses of DCD and ADHD with significant ASS traits (2.2%). Another child is diagnosed with DCD, ADHD, and dyslexia, exhibiting significant ASS characteristics (2.2%). Similarly, one adolescent has diagnoses of both DCD and dyslexia, also demonstrating significant ASS traits (2.2%). Furthermore, one child contends with ADHD, dyslexia, and DCD (2.2%). Another child faces ADD, dyslexia, and DCD (2.2%). Similarly, one adolescent copes with dyslexia, dyscalculia, and DCD (2.2%). Lastly, one child has diagnoses of DCD, dysorthography, and ADHD (2.2%). Accounting for suspected comorbidities and significant characteristics, 19 participants experience 1 comorbidity, 7 children face 2 comorbidities, and 2 children confront 3 comorbidities.

Materials

The materials were based on the study of Desli and Giakoumi (2017). Their study encompasses eight length estimation tasks (see Table 3). Originally, these tasks addressed four primary factors that could impact child's length estimation performances: object orientation, visual interference, representations of standard measurement units and spatial dimensionality. Due to practical limitations (in both task 5 and 6 three-dimensional objects were shown), spatial dimensionality was not used in this thesis (differentiating between real-word three-dimensional objects and two-dimensional images of real-world objects). Each of the 8 tasks comprised 2 items, resulting in a total of 16 items. In each task, two types of measurement units were employed (except for task 7 and 8): standard units (centimeters) and nonstandard units (such as pencils, paperclips, and straws). Half of the objects were short, ranging from 5 to 30 cm, while the other half were long, spanning 70 to 100 cm. At the beginning of each task, participants were presented with both standard and nonstandard units for proper reference (e.g. "This is one cm *(shown on ruler).* How long do you think this object is in cm *(shown object to be estimated)*?" For each subtask, the reference is shown again).

Table 3

Description of the Tasks Used in the Present Study

Category	Task Description	Material	Measurement Units: Standard Units	Measurement Units: Nonstandard Units
Object Orientation	Task 1. Horizontal orientation	Wooden rod of 20 cm Wooden rod of 90 cm	Centimeters	Pencils
	Task 2. Vertical orientation	Wooden rod of 30 cm Wooden rod of 100 cm		
Visual Interference	Task 3. White background	White paper with black stripe of 15 cm White paper with black stripe of 80 cm	Centimeters	Straws
	Task 4. Background with a complex pattern	Paper with complex background with a black stripe of 25 cm Paper with complex background with a black stripe of 85 cm		

~~Spatial Dimensionality~~	Task 5. Three-dimensional object	Photoframe of 18 cm White rope of 80 cm	Centimeters	Paperclips
	Task 6. Three-dimensional object	Rubber of 5 cm Belt of 80 cm		
Representation of standard measurement units	Task 7. Draw a line	Need to indicate 10 cm with tape Need to indicate 70 cm with tape	Centimeters	
	Task 8. Indicate an object	Find rope of 10 cm between ropes of different lengths Find rope of 70 cm between ropes of different lengths		

Note. The spatial dimensionality tasks have been excluded in the results because of practical limitations. In task six, the objects should have been shown on two-dimensional images to investigate spatial dimensionality. From Children's length estimation performance and strategies in standard and non-standard units of measurement. *International Journal for Research in Mathematics Education, 7*(3), 61-84. Desli, D., & Giakoumi, M. (2017).

Tasks one and two investigated the impact of object orientation on estimation performances (Desli & Giakoumi, 2017). In task one, a wooden rod was presented horizontally, while in task two, it was displayed vertically. Children were tasked with estimating its length using centimeters as the standard unit and pencils as the nonstandard unit. Tasks three and four explored the influence of visual interference on estimation performances. Task three required participants to estimate the length of a black line drawn on white paper, whereas task four involved a black line on a paper with a complex background, making visual isolation more challenging. Estimations in tasks three and four were conducted using centimeters and straws. Task five involved estimating the lengths of real-world three-dimensional objects - a photo frame and a rope – while task six should have presented participants with two-dimensional images of two real-word objects - a rubber and a belt. Due to practical limitations, the items in task six have been shown as three-dimensional objects as well. Estimations in tasks five and six were made using centimeters and paperclips. Tasks seven and eight investigated the impact of children’s understanding of standard units of measurement on length estimation. In task seven, participants were asked to draw a line of a specified length, while in task eight, they were shown real-world objects of certain lengths (ropes in this study) and asked to identify which rope matched the given length. The lengths in tasks seven and eight remained constant to focus on the effect of the type of object (line or three-dimensional object). The tasks were presented in two orders: tasks one to eight or tasks five to eight followed by one to four. Participants with even-numbered identifiers completed tasks one to eight, while those with odd-numbered identifiers completed tasks five to eight first, followed by tasks one to four. Participant numbers were generated by combining the initials of the test leader with a numerical suffix starting from one (Desli & Giakoumi, 2017).

Procedure

The procedure was adapted from the study by Desli and Giakoumi (2017). Prior to conducting the study, the researcher visited the specific school involved. A presentation was delivered to the special education attendants, outlining the procedure and design of the study. Attendees were provided with the opportunity to acquaint themselves with the instructions (see Appendix A) and ask any questions they had. The administrations of the instrument were conducted individually by the children's special education attendants in a quiet setting within the school premises, with responses recorded for analysis. Prior to commencing the administration, children were reassured that there were no wrong or right answers, and their estimations would not be used for evaluation purposes. Informed consent forms were provided to parents before participation (see Appendix B), emphasizing the voluntary nature of involvement and guaranteeing anonymity. The administrations of the instrument were conducted verbally and they were shown objects visually, with attendants offering general praise to the children throughout, though no specific feedback was provided. Children were given ample time to complete the administration of the instrument, as no time restrictions were imposed. On average, the administration of the instrument lasted approximately 20 to 25 minutes.

Data Coding

A lenient scoring method, following the data coding approach of Desli and Giakoumi (2017), was implemented. This method considered an approximation as correct. Desli and Giakoumi (2017) defined justifiable estimates as those falling within 30% of the correct answer (see Table 4), drawing from the research of Dowker (1992). One point was awarded if the child's response fell within this 30% range, while zero points were given otherwise (Desli & Giakoumi, 2017). In task 3, item 1, using nonstandard units, the permissible range of 30% does not encompass a whole number. Anticipating that most children would provide whole number responses, the upper limit was adjusted to 1.01.

Table 4

Permissible Range of 30% Around the Correct Answer

Item	Correct	Unit	Lower Bound	Upper Bound
1A1	20	Centimeter	14	26.00
1A2	1.14	Pencils	0.798	1.48
1B1	90	Centimeter	63	117.00
1B2	5.14	Pencils	3.598	6.68
2A1	30	Centimeter	21	39.00
2A2	1.71	Pencils	1.197	2.22
2B1	100	Centimeter	70	130.00
2B2	5.71	Pencils	3.997	7.42
3A1	15	Centimeter	10.5	19.50
3A2	0.71	Straws	0.497	1.01
3B1	80	Centimeter	56	104.00
3B2	3.81	Straws	2.667	4.95
4A1	25	Centimeter	17.5	32.50
4A2	1.19	Straws	0.833	1.55
4B1	85	Centimeter	59.5	110.50
4B2	4.05	Straws	2.835	5.27
5A1	18	Centimeter	12.6	23.40
5A2	7.2	Paperclips	5.04	9.36
5B1	80	Centimeter	56	104.00
5B2	32	Paperclips	22.4	41.60
6A1	5	Centimeter	3.5	6.50
6A2	2	Paperclips	1.4	2.60
6B1	65	Centimeter	45.5	84.50
6B2	26	Paperclips	18.2	33.80
7A	10	Centimeter	7	13.00
7B	70	Centimeter	49	91.00
8A	10	Centimeter	7	13.00
8B	70	Centimeter	49	91.00

Note. This table displays the 30% permissible range around the precise answer. If they report a number falling within this interval, their answer is considered correct. The item number compounds different parts. The first number corresponds with the task number. The letter A represents the short items, while the letter B represents the long items. The last number represents the type of measurement unit. Number one represents the standard units (cm), while number two represents the nonstandard units (such as pencils, straws, paperclips). Task seven and eight only consisted of estimations in standard units.

The mean performance for each participant was calculated by summing the correct responses per respondent and dividing by the total number of questions, resulting in an average performance indicator for each respondent. These individual measures of mean performance allowed researchers to compare different categories of respondents. Different grouping variables such as level of education (d, da and a finality) and age (younger or older than 15) were used.

Furthermore, the mean performance on each question was also calculated by summing the correct responses per item and dividing by the total number of respondents, resulting in an average performance indicator for each item. These individual measures of mean performance allowed researchers to compare different categories of items. Different grouping variables such as the orientation of the object and length of an object were used.

Task six should have included two-dimensional images (Desli & Giakoumi, 2017), but this study used three-dimensional objects instead. Thus, spatial dimensionality was not analyzed separately, while Desli and Giakoumi (2017) did analyze this as they did use two-dimensional images for task 5. Estimating the length of an image was deemed overly complex, e.g. an image of a belt of 80 cm, on a normal-sized two-dimensional paper.

In hindsight, researchers realized the rope lengths used in task 8 were too indifferent, therefore resulting in all answers being considered correct. For instance, with length A being the correct answer, lengths B, C, and D would also have been considered correct under the permissible range of 30%. The study on which our instrument was based (Desli & Giakoumi, 2017) did keep task 8.

Average score per respondent was calculated based on the first six tasks, task seven was analyzed by itself using percentage absolute error. Task 8 was not further analyzed because all the shown ropes fell within the permissible range, rendering this question moot.

Results

Mean Rate of Correct Responses

Total Score

There are large individual differences in estimation performances when we compute the average performance from task 1-6. The performances range from 16.67% to 95.83% (*M* = 61.48%, *SD* = 20.66%).

Level of Education

When looking at the level of education, three data entries are missing, which are excluded in the calculations of the rate of correct responses concerning level of education. A one-way analysis of variance (ANOVA) has been conducted to look at the effect of level of education (d, da, a finality) on estimation performances. The results indicate an absence of a significant effect of level of education (*F*(2, 39) = 1.05, *p* = .36), indicating that the level of education did not influence the estimation performances of children with DCD.

To compare the estimation performances between two different finalities, independent samples *t*-tests have been carried out. The difference between children in the d-finality (*M* = 65.76%, *SD* = 20.91%) and the children in the d/a-finality (*M* = 62.50%, *SD* = 16.78%) was not significant, *t*(31) = 0.44, *p* = .67. The difference between children in the d-finality (*M* = 65.76%, *SD* = 20.91%) and the children in the a-finality (*M* = 54.17%, *SD* = 22.24%) was not significant, *t*(30) = 1.39, *p* = .18. The difference between children in the d/a-finality (*M* = 62.50%, *SD* = 16.78%) and the children in the a-finality (*M* = 54.17%, *SD* = 22.24%) was also not significant, *t*(17) = 0.93, *p* = .37. The level of education did not influence the estimation performances of children with DCD, as seen before. For all independent samples *t*-tests equal variance is assumed given that the Levene’s test for equality of variances yields a *p*-value higher than 0.05 for all three *t*-tests.

Age

A Pearson correlation between the percentage of correct responses and age has also been calculated. The correlation was insignificant (*r* = .15, *p* = .32). This suggests that there is no association between the estimation performances and age. We further categorized the children in two groups according to age. The first category includes children under and equal to the age of 15 years, the second category includes children of 16 years and older. Furthermore, to compare the estimation performances between children with different ages, an independent sample *t*-test has been carried out. The difference between children of 16 years old and older in estimation performances (*M* = 64.10%, *SD* = 17.88%) and children under and equal to the age of 15 years old (*M* = 60.42%, *SD* = 21.87%) is not significant, *t*(43) = -0.54, *p* = .59, indicating that age does not have an effect on the estimation performances.

Comorbidity

We categorized the children in six different categories depending on their comorbidity. These six categories were the following: no comorbidity (*n* = 16), only having dyslexia or another language disorder such as dysphasia (*n* = 7), only having ASS and/or AD(H)D (*n* = 10), only having dyscalculia (*n* = 3), only having epilepsy (*n* = 1) and lastly, having multiple of the beforementioned comorbidities (*n* = 7). It was unclear whether one child had a comorbidity, so this person was excluded for this analysis. One child suffers from diabetes. This disorder has not been used for categorizing. When calculating the mean percentage of correct responses the following results were found (see Table 5).

A one-way analysis of variance (ANOVA) has been conducted on these groups (see Table 5) to examine the effect of these comorbidities on estimation performances. The results were insignificant ($F(5,38) = 1.43$, $p = .24$) indicating that a potential comorbidity did not impact the estimation performances of the children.

Table 5

Mean Percentage of Correct Responses and Standard Deviation per Comorbidity

Number of Group	**Comorbidity**	**Number of Participants**	**Mean**	**Standard Deviation**
1	None	16	57.03%	19.47%
2	Only dyslexia or another language disorder such as dysphasia	7	67.86%	26.32%
3	Only ASS and/or AD(H)D	10	62.50%	19.35%
4	Only dyscalculia	3	59.72%	17.35%
5	Only epilepsy	1	16.67%	
6	Multiple	7	67.86%	16.26%

Note. Group 2 includes one child of whom there was no official diagnosis of dyslexia, but of which it is suspected. Group 3 also includes one child who was diagnosed with ADHD but does not show active signals of ADHD anymore thus does not take any medication. Another child in this group has been diagnosed with ADHD and shows sign of ASS. Group 6 includes children who suffer from multiple comorbidities of various of the beforementioned groups. One child of this group suffers from ADHD and dyslexia and shows signs of ASS. Another child in this group suffers from both dysorthography and ADHD. One child also has been added to this group who suffers from dyslexia and shows signs of ASS.

Type of Unit Measurement

When conducting a Pearson correlation between the items in standard units (in cm) and the items in nonstandard units (in number of pencils, straws, paperclips), an insignificant correlation has been found (r = -.24, p = .25), indicating that there was no relationship between estimations in standard units and estimations in nonstandard units.

For comparing the estimations on the standard (in cm) versus nonstandard items (in number of pencils, straws, paperclips), an independent samples *t*-test has been conducted. The difference between the estimations in standard units (*M* = 65.37%, *SD* = 9.11%) and the estimations in nonstandard units (*M* = 57.59%, *SD* = 20.99%), is not significant, *t*(15) = 1.18, *p* = .26, indicating that the type of measurement unit does not influence the estimation performance of children with DCD. For this independent samples *t*-tests equal variance is not assumed given that the Levene's test for equality of variances yields a *p*-value lower than 0.05.

Orientation of Object

The mean percentage of correct responses on the items shown horizontally is 64.45% (*SD* = 12.17%). The mean percentage of correct responses on the items shown vertically is 63.33% (*SD* = 20.33%). An independent samples *t*-test, *t*(6) = 0.09, *p* = .93, was conducted and showed no significant difference in estimation performance.

Length of Object

When comparing the estimations between the short items and the long items, an independent samples *t*-test has been conducted. The difference between the short items (*M* = 71.67%, *SD* = 11.18%) and the long items (*M* = 51.30%, *SD* = 14.32%) is significant, *t*(22) = 3.88, *p* < .001. This suggests that the length of the object influences estimation performance in children with DCD. The estimations for the short items were better than those for the long items. For this independent samples *t*-tests equal variance is assumed given that the Levene's test for equality of variances yields a *p*-value higher than 0.05.

Presence of Visual Interference

For comparing the estimations between the items with visual interference and without visual interference, an independent samples *t*-test has been conducted. The difference between the items with visual interference (*M* = 63.89%, *SD* = 9.67%) and the items with no visual interference (*M* = 60.00%, *SD* = 18.42%) is insignificant, *t*(6) = 0.37, *p* = .72. This indicates that the presence of visual interference does not influence the estimation performance. For this independent samples *t*-tests equal variance is assumed given that the Levene's test for equality of variances yields a *p*-value higher than 0.05.

Task Seven: Drawing a Line

For task seven, the percentage absolute error (PAE) is calculated. This represents the absolute difference between the actual and the reported value, standardized as a percentage. A low PAE means that the actual and the reported value only differ slightly in comparison to a large PAE. When the actual value is the same as the reported value, the PAE is 0%.

The actual length of the short line is 10 cm. The PAE ranges from 0% to 290% (*M* = 72.93%, *SD* = 69.78%) for this line. This indicates varying degrees of accuracy in estimating the short length across students.

The actual length of the long line is 70 cm. The PAE ranges from 0% to 332.4% (*M* = 40.68%, *SD* = 58.87%) for this line. This indicates varying degrees of accuracy in estimating the long length across students.

Length of Line

A Pearson correlation has been conducted to look at a potential relationship between the estimates for the short (*M* = 72.93%, *SD* = 69.78%) and the long line (*M* = 40.68%, *SD* = 58.87%). When performing this correlation between these two variables, a significant positive correlation has been found (*r* = .43, *p* = .003), suggesting a relationship between estimates for short and long lines.

Level of Education

Short Line. A one-way analysis of variance has been conducted to examine the effect of the level of education on the task ‘drawing a line’. Children in the d-finality had a mean of 63.43% and a standard deviation of 58.57% for the short line. Children in the d/a-finality had a mean of 65.80% and a standard deviation of 54.41% for the short line. Children in the a-finality had a mean of 112.78% and a standard deviation of 105.98% for the short line. The result of the one-way analysis of variance was insignificant for the short line (F(2,39) = 1.70, p = .20), indicating that level of education does not influence estimation performances for short lines.

Long Line. Children in the d-finality had a mean of 44.94% and a standard deviation of 70.92% for the long line. Children in the da-finality had a mean of 34.00% and a standard deviation of 44.89% for the long line. Children in the a-finality had a mean of 41.43% and a standard deviation of 48.13% for the long line. The result of the one-way analysis of variance was also insignificant for the long line (*F*(2,39) = 0.11, *p* = .90), indicating that level of education does not influence estimation performances for long lines.

Age

Short Line. An independent samples *t*-test has been conducted to examine the effect of age on the task 'drawing a line'. The mean percentage of correct responses of children under or equal the age of 15 was 71.06% with a standard deviation of 70.70% for the short line. The mean percentage of correct responses of children of 16 years or older was 77.54% with a standard deviation of 70.05% for the short line. The result of the independent samples t-test was insignificant, *t*(43) = -0.28, *p* = .78, indicating that age does not influence estimation performances for short lines. For this independent samples *t*-tests equal variance is assumed given that the Levene's test for equality of variances yields a *p*-value higher than 0.05.

Long Line. An independent samples *t*-test has been conducted to examine the effect of age on the task 'drawing a line'. The mean percentage of correct responses of children under or equal to the age of 15 years was 42.05% with a standard deviation of 62.13% for the long line. The mean percentage of correct responses of children of 16 years or older was 37.31% with a standard deviation of 52.12% for the long line. The result of the independent samples t-test was insignificant, *t*(43) = 0.24, *p* = .81, indicating that age does not influence estimation performances for long lines. For this independent samples *t*-tests equal variance is assumed given that the Levene's test for equality of variances yields a *p*-value higher than 0.05.

Comorbidity

Short Line. A one-way analysis of variance has been conducted to examine the effect of comorbidities on the task 'drawing a line' for the short line. They were categorized in different groups, the same as mentioned before. A one-way analysis of variance (ANOVA) has been conducted on these groups to examine the effect of these comorbidities on estimation performances for the short line (see Table 6). The results were insignificant (*F*(5,38) = 1.80, *p* = .13), suggesting that comorbidity does not impact the estimation performances for short lines.

Table 6

Mean Percentage Absolute Error and Standard Deviation per Comorbidity for the Short Line

Number of Group	Comorbidity	Number of Participants	Mean	Standard Deviation
1	None	16	87.50%	82.02%
2	Only dyslexia or another language disorder such as dysphasia	7	46.71%	32.87%
3	Only ASS and/or AD(H)D	10	61.20%	73.15%
4	Only dyscalculia	3	118.33%	34.03%
5	Only epilepsy	1	210.00%	
6	Multiple	7	42.57%	50.51%

Note. Group 2 includes one child of whom there was no official diagnosis of dyslexia, but of which it is suspected. Group 3 also includes one child who was diagnosed with ADHD but does not show active signals of ADHD anymore thus does not take any medication. Another child in this group has been diagnosed with ADHD and shows sign of ASS. Group 6 includes children who suffer from multiple comorbidities of various of the beforementioned groups. One child of this group suffers from ADHD and dyslexia and shows signs of ASS. Another child in this group suffers from both dysorthography and ADHD. One child also has been added to this group who suffers from dyslexia and shows signs of ASS.

Long Line. A one-way analysis of variance has been conducted to examine the effect of comorbidities on the task ‘drawing a line’ for the long line. They were categorized in different groups, the same as beforementioned. A one-way analysis of variance (ANOVA) has been conducted on these groups to examine the effect of these comorbidities on estimation performances for the long line (see Table 7). The results were significant (*F*(5,38) = 4.61, *p* = .002), suggesting that comorbidities affect the estimation performances for long lines.

Table 7

Mean Percentage Absolute Error and Standard Deviation per Comorbidity for the Long Line

Number of Group	Comorbidity	Number of Participants	Mean	Standard Deviation
1	None	16	35.94%	41.48%
2	Only dyslexia or another language disorder such as dysphasia	7	19.59%	27.06%
3	Only ASS and/or AD(H)D	10	33.21%	42.50%
4	Only dyscalculia	3	172.14%	145.69%
5	Only epilepsy	1	57.86%	
6	Multiple	7	30.31%	28.82%

Note. Group 2 includes one child of whom there was no official diagnosis of dyslexia, but of which it is suspected. Group 3 also includes one child who was diagnosed with ADHD but does not show active signals of ADHD anymore thus does not take any medication. Another child in this group has been diagnosed with ADHD and shows sign of ASS. Group 6 includes children who suffer from multiple comorbidities of various of the beforementioned groups. One child of this group suffers from ADHD and dyslexia and shows signs of ASS. Another child in this group suffers from both dysorthography and ADHD. One child also has been added to this group who suffers from dyslexia and shows signs of ASS.

A Tukey's Honestly Significant Differences (HSD) test has been carried out to determine which groups do better than others (see Table 8). Group 5 has been excluded here due to only having one participant. The children of group 4 have significantly lower mean scores than the children of group 1 ($p < .001$), group 2 ($p < .001$), group 3 ($p = .001$), and group 6 ($p = .002$). This indicates that children who solely have dyscalculia and DCD perform significantly poorer than children without a comorbidity, with solely ASS and/or AD(H)D and DCD, with solely dyslexia and DCD or another language disorder such as dysphasia and DCD, and with multiple comorbidities. There were no significant differences between the other groups.

Table 8

Significant Multiple Comparisons With Group 4: Tukey HSD

Group X	Mean Difference (Group 4 – Group X)	Standard Error
Group 1	136.21	31.27
Group 2	152.55	34.30
Group 3	138.93	32.72
Group 6	141.84	34.30

Note. See Table 6 for accurate descriptions of the groups.

Discussion

The main research question entails potential effects of various characteristics of features and variables such as age, level of education and possible comorbidities on estimation performances in children with DCD. This has been looked at through a design based on Desli and Giakoumi (2017). In this study, 45 children with DCD have participated (age range: 12-18, M = 15.11 years). Performance on different length estimation tasks was measured. Various characteristics of features were considered such as type of unit measurement, the presence of visual interference, the length of the objects and the orientation in which an object is shown. The effect of level of education, age and potential comorbidities also have been investigated.

First, personal characteristics such as age, level of education and comorbidity do not influence the estimation performances of the children with DCD. There is one exception: comorbidity did influence the performance on the estimation responses of task 7 concerning the long line. In this task, they were asked to draw a line of a specific length. Children with solely dyscalculia and DCD performed poorer than children without a comorbidity, with solely ASS and/or AD(H)D and DCD, with solely dyslexia or another language disorder such as dysphasia and DCD, and with multiple comorbidities.

Thereafter, the effect of item characteristics of features on estimation performance in children with DCD has been investigated, such as the length of an object, the orientation in which an object is shown, the presence of visual interference, and the type of unit measurement. Solely the length of objects does have an effect on estimation performance with better estimates for short items than for long items. Furthermore, a positive relationship has been found between the short and long items for the percentage absolute error when drawing a line of a specific length.

Integration of the Results With Previous Studies

There is a lack of knowledge surrounding estimation performances of individuals with DCD. But cognitive processes in these individuals are diminished in comparison to individuals without DCD (Asonitou et al., 2012). Particularly, studies regarding mathematical skills show a lower level of mathematical abilities in comparison to individuals with no DCD (Reynvoet et al., 2020; Vaivre-Douret et al., 2011).

The instrument in this study is based on the design of Desli and Giakoumi (2017). In their study, 46 third graders and 41 fifth graders participated. They have found a difference in estimation performances between third graders (8-9 years old) and fifth graders (10-11 years old). Differences between the study of Desli and Giakoumi (2017) and this research paper, regarding the personal characteristics (such as level of education, possible comorbidity), could be caused by the difference in age. Additionally, the children in the study of Desli and Giakoumi (2017) were still in primary school while the children in our study attended secondary school. The children in the study of Desli and Giakoumi (2017) were recruited out of schools in urban areas in Greece, while our study recruited the participants in Belgium and did not consider a possible difference between children attending school in rural and urban areas. When looking at characteristics of features, the length of objects did not have a effect in the study of Desli and Giakoumi (2017), while our study found that the performance for short items was better than the performance for long items. Desli and Giakoumi (2017) found that length estimates were better for nonstandard units of measurement than for standard units. This difference was not found in our study. It may be possible that there is a difference in the findings surrounding the characteristics of features since the items in the study of Desli and Giakoumi (2017) and our study were not completely the same (e.g. a belt of 65 cm in the study of Desli and Giakoumi, 2017 versus a belt of 80 cm in our study).

Limitations and Future Research

This study has some limitations. The first has to do with our participant sample and namely the absence of a control condition. Given the explorative nature of this study, the decision was made to prioritize in-depth data gathering based on a specific sample, namely children with DCD. This led researchers to focus on the target group, namely children with DCD, and to exclude control conditions from the design. The absence of a control condition prohibits the ability to compare and thus more accurately measure the influence of DCD on children's estimation performances. Future research should therefore augment this study's findings by using a control condition.

In our study, spatial dimensionality was not investigated since the items of task 6 should have been shown two-dimensionally instead of three-dimensionally. Furthermore, task 8 was omitted from the analysis in our study since all answers fell within the permissible range of 30% and thus were considered correct. Future research can make better decisions regarding these items.

Contrary to the study of Desli an Giakoumi (2017), the use of estimation strategies has not been taken into account in the present study. This can give extra valuable information on how exactly individuals with DCD make their estimates. The research of Joram et al. (1998) tells us that students and adults usually favor three estimation strategies: unit iteration, decomposition/recomposition, and reference point/benchmark. Unit iteration is done by iterating a mental image of a standard unit over the to-be-estimated object. Further, the estimator mentally decomposes the to-be-estimated object into smaller parts, followed by estimating the length of each part and then adding or multiplying these lengths in the decomposition/recomposition strategy. Lastly, the estimator uses a mental image of a nonstandard unit (e.g. pencil which is known to be 20 cm) and iterates it over the to-be-estimated object in the reference point/benchmark strategy. Future research can take this into account as well. This way, strategy use for estimation can be investigated regarding children, or people, who have DCD. Maybe these individuals can learn strategies which usually give more accurate estimations, if it is noticed that individuals with DCD use poorer performing strategies.

One of the other limitations encompasses the impact of a potential comorbidity on participants' estimation performances. The participants can experience issues in estimating due to potential comorbidities instead of just because of their DCD. This study found that children with dyscalculia and DCD performed poorer on the task where they needed to draw a line of a long length than children with other comorbidities and with no comorbidity, besides DCD. Previous research found that results of children with developmental dyscalculia differ from children without mathematical difficulties in various estimation tasks such as the dot comparison and number line task, as well as in both numerical and non-numerical ordering skills (Morsanyi et al., 2018). The dot comparison task measures non-symbolic magnitude comparison abilities and the number line task measures the ability to translate between symbolic and non-symbolic representations of magnitudes and is also assumed to include an ordering component (Morsanyi et al., 2018). Considering this is demand-driven research, deriving predictions from the studies presented above should be done with great care.

Conclusion

This research found big individual differences between the individuals, meaning that the group of children with DCD is heterogeneous. The estimation performance of children with DCD in this study (12-18 yrs.) was not much better than the performance of the elementary school children of Desli and Giakoumi (2017), although there was no real control condition in this research paper. Personal characteristics such as age, level of education and comorbidity had (almost) no influence on the estimation performances of children with DCD. Children with solely dyscalculia and DCD showed poorer performance than children without a comorbidity, with solely ASS and/or AD(H)D and DCD, with solely dyslexia and DCD or another language disorder such as dysphasia and DCD, and with multiple comorbidities when asked to draw a long line of a specific length. Item characteristics such as orientation of object, presence of visual interference and the type of measurement unit did not influence the estimation performance of children with DCD, but the length of the to-be-estimated object did. The estimations for the short items were better than those for the long items. The current insights may be a setting stone to develop compensating strategies that children with DCD can use when estimation is necessary, e.g. in daily life.

References

Alloway, T.P. (2007). Working memory, reading, and mathematical skills in children with developmental coordination disorder. *Journal of Experimental Child Psychology, 96*(1), 20-36. https://doi.org/10.1016/j.jecp.2006.07.002

American Psychiatric Association. (2013). Neurodevelopmental Disorders. In *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.). https://doi.org/10.1176/appi.books.9780890425596

Asonitou, K., Koutsouki, D., Kourtessis, T., & Charitou, S. (2012). Motor and cognitive performance differences between children with and without developmental coordination disorder (DCD). *Research in Developmental Disabilities, 33*(4), 996-1005. https://doi.org/10.1016/j.ridd.2012.01.008

Boitteau, M., Albaret, J.-M., & Chaix, Y. (2020). Developmental coordination disorder. In A. Gallagher, C. Bulteau, D. Cohen, & J. L. Michaud (Eds.), *Neurocognitive Development: Disorders and Disabilities* (Vol. 174, 3rd ed., pp. 3-20). Elsevier B.V. https://doi.org/10.1016/B978-0-444-64148-9.00001-6

Boitteau, M., Chaix, Y., Blais, M., Tallet, J., Péran, P., & Albaret, J.-M. (2016). Neural signature of DCD: A critical review of MRI neuroimaging studies. *Frontiers in Neurology, 7*(227). https://doi.org/10.3389/fneur.2016.00227

Brown, T., & Rodger, S. (2008). Validity of the developmental test of visual-motor integration supplemental developmental test of visual perception. *Perceptual and Motor Skills, 106*(3), 659-678. https://doi.org/10.2466/pms.106.3.659-678.

Cairney, J., & King-Dowling, S. (2016). Developmental Coordination Disorder. In J. Matson (Eds.), *Comorbid Conditions Among Children with Autism Spectrum Disorders. Autism and Child Psychopathology Series* (pp. 303-322). Springer, Cham. https://doi.org/10.1007/978-3-319-19183-6_13

Chang, K. L., Males, L. M., Mosier, A., & Gonulates, F. (2011). Exploring US textbooks' treatment of the estimation of linear measurements. *ZDM Mathematics Education, 43(*5), 697–708. https://doi.org/10.1007/s11858-011-0361-2

Cousins, M., & Smyth, M. M. (2003). Developmental coordination impairments in adulthood. *Human Movement Science*, *22*(4-5), 433-459. https://doi.org/10.1016/j.humov.2003.09.003

Delgado-Lobete, L., Santos-Del-Riego, S., Pértega-Díaz, S., & Montes-Montes, R. (2019). Prevalence of suspected developmental coordination disorder and associated factors in Spanish classrooms. *Research in Developmental Disabilities, 86,* 31-40. https://doi.org/10.1016/j.ridd.2019.01.004

Desli, D., & Giakoumi, M. (2017). Children's length estimation performance and strategies in standard and non-standard units of measurement. *International Journal for Research in Mathematics Education, 7*(3), 61-84. http://funes.uniandes.edu.co/26626/1/Desli2017Childrens.pdf

Dowker, A. (1992). Computational estimation strategies of professional mathematicians. *Journal of Research in Mathematics Education, 23*(1), 45-55. https://doi.org/10.2307/749163

Gandini, D., Lemaire, P., & Dufau, S. (2008). Older and younger adults' strategies in approximate quantification. *Acta Psychologica, 129*(1), 175-189. https://doi.org/10.1016/j.actpsy.2008.05.009

Girish, S., Raja, K., & Kamath, A. (2016). Prevalence of developmental coordination disorder among mainstream school children in India. *Journal of Pediatric Rehabilitation Medicine*, *9*(2), 107-116. https://doi.org/10.3233/PRM-160371

Gooya, Z., Khosroshahi, L.G., & Teppo, A.R. (2011). Iranian students' measurement estimation performance involving linear and area attributes of real-world objects. *ZDM Mathematics Education, 43*(5), 709-722. https://doi.org/10.1007/s11858-011-0338-1

Hogan, T. P., & Brezinski, K. L. (2003). Quantitative estimation: One, two, or three abilities? *Mathematical Thinking and Learning, 5*(4), 259-280. https://doi.org/10.1207/S15327833MTL0504_02

Hoth, J., Heinze, A., Huang, H.-M. E., Weiher, D. F., Niedermeyer, I., & Ruwisch, S. (2023). Elementary school students' length estimation skills – analyzing a multidimensional construct in a cross-country study. *International Journal of Science and Mathematics Education, 21*, 1841-1864. https://doi.org/10.1007/s10763-022-10323-0

Huang, H.-M.E. (2020). Effects of grade level and object size on students' measurement estimation performance. *Eurasia Journal of Mathematics, Science and Technology Education, 16*(12), 1-16. https://doi.org/10.29333/ejmste/9342

Jones, M.G., Gardner, G.E., Taylor, A.R., Forrester, J.H., & Andre, T. (2012). Students’ accuracy of measurement estimation: Context, units, and logical thinking. *School Science and Mathematics, 112*(3), 171-178. https://doi.org/10.1111/j.1949-8594.2011.00130.x

Jones, M.G., & Taylor, A.R. (2009). Developing a sense of scale: Looking backward. *Journal of Research in Science Teaching, 46*(4), 460-475. https://doi.org/10.1002/tea.20288

Joram, E., Subrahmanyam, K., & Gelman, R. (1998). Measurement estimation: Learning to map the route from number to quantity and back. *Review of Educational Research, 68*(4), 413-449. https://doi.org/10.3102/00346543068004413

Kirby, A., Sugden, D., Beveridge, S., & Edwards, L. (2008). Developmental co-ordination disorder (DCD) in adolescents and adults in further and higher education. *Journal of Research in Special Educational Needs, 8*(3), 120-131. https://doi.org/10.1111/j.1471-3802.2008.00111.x

LeFevre, J.-A., Greenham, S. L., & Waheed, N. (1993). The development of procedural and conceptual knowledge in computational estimation. *Cognition and Instruction, 11*(2), 95-132. https://doi.org/10.1207/s1532690xci1102_1

Luwel, K., Verschaffel, L., Onghena, P., & De Corte, E. (2000). Children’s strategies for numerosity judgement in square grids of different sizes. *Psychologica Belgica, 40*(3), 183-209. https://doi.org/10.5334/pb.962

Morsanyi, K., van Bers, B.M.C.W., O’Connor, P.A., & McCormack, T. (2018). Developmental dyscalculia is characterized by order processing deficits: Evidence from numerical and non-numerical ordering tasks. *Developmental Neuropsychology*, *43*(7), 595-621. https://doi.org/10.1080/87565641.2018.1502294

Onderwijs Vlaanderen. (n.d.). *Het voltijds gewoon secundair onderwijs.* https://onderwijs.vlaanderen.be/nl/secundair/het-voltijds-gewoon-secundair-onderwijs

Onderwijskiezer. (n.d.). *Modernisering van het secundair onderwijs in een notendop.* https://www.onderwijskiezer.be/v2/secundair/sec_modernisering.php

Peters, L.H.J., Maathuis, C.G.B., & Hadders-Algra, M. (2013). Neural correlates of developmental coordination disorder. *Developmental Medicine & Child Neurology, 55*(4), 59-64. https://doi.org/10.1111/dmcn.12309

Pieters, S., Desoete, A., Van Waelvelde, H., Vanderswalmen, R., & Roeyers, H. Mathematical problems in children with developmental coordination disorder. *Research in Developmental Disabilities, 33*(4), 1128-1135. https://doi.org/10.1016/j.ridd.2012.02.007

Polatajko, H., Fox, M., & Missiuna, C. (1995). An international consensus on children with developmental coordination disorder. *The Canadian Journal of Occupational Therapy, 62*(1), 3-6. https://doi.org/10.1177/000841749506200101

Reynvoet, B., Marinova, M., & Sasanguie, D. (2020). Take it of your shoulders: Providing scaffolds leads to better performance on mathematical word problems in secondary school children with developmental coordination disorder. *Research in Developmental Disabilities, 105*. https://doi.org/10.1016/j.ridd.2020.103745

Ruiz, C., Kohnen, S., & Bull, R. (2023). The relationship between number line estimation and mathematical reasoning: A quantile regression approach. *European Journal of Psychology of Education.* https://doi.org/10.1007/s10212-023-00708-2

Sarama, J., Clements, D. H., Barrett, J. E., Cullen, C. J., Hudyma, A., & Vanegas, Y. (2022). Length measurement in the early years: Teaching and learning with learning trajectories. *Mathematical Thinking and Learning, 24*(4), 267–290. https://doi.org/10.1080/10986065.2020.1858245

Siegel, A.W., Goldsmith, L.T., & Madson, C.R. (1982). Skill in estimation problems of extent and numerosity. *Journal for Research in Mathematics Education, 13*(3), 211-232. https://doi.org/10.2307/748557

Siegler, R. S., & Booth, J. L. (2005). Development of numerical estimation: A review. In J. I. D. Campbell (Ed.), *Handbook of mathematical cognition* (pp. 197-212). Psychology Press.

Smits-Engelsman, B. C., Jover, M., Green, D., Ferguson, G., & Wilson, P. (2017). DCD and comorbidity in neurodevelopmental disorder: How to deal with complexity? *Human Movement Science, 53,* 1-4. https://doi.org/10.1016/j.humov.2017.02.009

Sowder, J. (1992). Estimation and number sense. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 371-389). New York, NY: Macmillan.

Sujatha, B., Alagesan, J., Lal, D.V., & Rayna, A.B.S. (2020). Prevalence of developmental co-ordination disorder in school children. *The Indian Journal of Pediatrics, 87*(6), 454-456. https://doi.org/10.1007/s12098-020-03191-5

Vaivre-Douret, L., Lalanne, C., Ingster-Moati, I., Boddaert, N., Cabrol, D., Dufier, J.-L., Golse, B., & Falissard, B. (2011). Subtypes of developmental coordination disorder: Research on their nature and etiology. *Developmental Neuropsychology, 36*(5), 614-643. https://doi.org/10.1080/87565641.2011.560696

Vanbasisnaarsecundair. (n.d.). *Het secundair onderwijs.* https://pro.vanbasisnaarsecundair.be/schoolteams/het-secundair-onderwijs

Visser, J. (2003). Developmental coordination disorder: A review of research on subtypes and comorbidities. *Human Movement Science, 22*(4-5), 479-493. https://doi.org/10.1016/j.humov.2003.09.005

Waber, D.P., Boiselle, E.C., Yakut, A.D., Peek, C.P., Strand, K.E., & Bernstein, J.H. (2021). Developmental dyspraxia in children with learning disorders: Four-year experience in a referred sample. *Journal of Child Neurology, 36*(3), 210-221. https://doi.org/10.1177/0883073820966913

Wilson, P.H., Maruff, P., & Lum, J. (2003). Procedural learning in children with developmental coordination disorder. *Human Movement Science, 22*(4-5), 515-526. https://doi.org/10.1016/j.humov.2003.09.007

Wilson, P.H., Smits-Engelsman, B., Caeyenberghs, K., Steenbergen, B., Sugden, D., Clark, J., Mumford, N., & Blank, R. (2017). Cognitive and neuroimaging findings in developmental coordination disorder: New insights from a systematic review of recent research. *Developmental Medicine & Child Neurology, 59*(11), 1097-1203. https://doi.org/10.1111/dmcn.13530

Appendix A

Instructions

Fase 1: Materiaal

- Invulfiche
- Potlood van 17.5 cm
- Latje
- Houten staaf van 20 cm: A
- Houten staaf van 90 cm: B
- Houten staaf van 30 cm: C
- Houten staaf van 100 cm: D
- Rietje: 21 cm
- Wit papier met zwarte streep van 15 cm: A
- Wit papier met zwarte streep van 80 cm: B
- Wit zwart bedrukt papier met zwarte streep van 25 cm: C
- Grijs bedrukt papier met zwarte streep van 85 cm: D
- Paperclip: 2.5 cm
- Fotokader van 18 cm
- Wit touw van 80 cm
- Gom van 5 cm
- Riem van 80 cm
- Leeg groot papier (reserve): E
- Grijs touw: 10 cm
- Roze touw: 15 cm
- Geel touw: 5 cm
- Groen touw: 20 cm
- Bruin, zeemanskoord: 70 cm
- Rood touw: 60 cm
- Paars touw: 65 cm
- Blauw touw: 55 cm
- Voorwerp om audio-opnames te maken: zelf te voorzien
- Rol tape

Fase 2: Praktisch

Voorzie een rustige locatie. De kinderen worden individueel geïnterviewd. Maak een audio-opname. Laat ze ook het geïnformeerde toestemmingsformulier tekenen. Zelf feedback geven mag niet. Het duurt ongeveer 20 à 25 minuten. Ze mogen de touwen vastnemen.

Fase 3: Inleiding

"Hallo X, we gaan vandaag samen de lengtes van enkele voorwerpen schatten. Er zijn geen foute of juiste antwoorden. Je gaat ook niet geëvalueerd worden. Je antwoordt gewoon wat jij denkt dat het moet zijn.”

Noteer participantnummer

Noteer geboortejaar

Noteer geslacht

Noteer eventuele comorbiditeit(en)

<u>Fase 4: Test zelf</u>

Alle deelnemers met een even participantennummer doorlopen de volgende taakvolgorde: 1-2-3-4-5-6-7-8.

Alle deelnemers met een oneven participantennummer doorlopen de volgende taakvolgorde: 5-6-7-8-1-2-3-4.

<u>Fase 4.1: Taak 1</u> (nodig: potlood, latje, houten staaf van 20 cm: A, houten staaf van 90 cm: B)

Je toont wat een centimeter is op een latje.

Je toont een potlood.

a) Je toont de houten staaf van 20 cm: A in een horizontale oriëntatie.

   “Hoe lang denk je dat deze is in centimeters?” *noteer*

   “Hoeveel pennen zouden er passen in de lengte van de houten staaf?” *noteer*

b) Je toont de houten staaf van 90 cm: B in een horizontale oriëntatie.

   “Hoe lang denk je dat deze is in centimeters?” *noteer*

   “Hoeveel pennen zouden er passen in de lengte van de houten staaf?” *noteer*

<u>Fase 4.2: Taak 2</u> (nodig: potlood, latje, houten staaf van 30 cm: C, houten staaf van 100 cm: D)

Je toont wat een centimeter is op een latje.

Je toont een potlood.

a) Je toont de houten staaf van 30 cm: C in een verticale oriëntatie.

   “Hoe lang denk je dat deze is in centimeters?” *noteer*

   “Hoeveel pennen zouden er passen in de lengte van de houten staaf?” *noteer*

b) Je toont de houten staaf van 100 cm: D in een verticale oriëntatie.

“Hoe lang denk je dat deze is in centimeters?” *noteer*

“Hoeveel pennen zouden er passen in de lengte van de houten staaf?” *noteer*

Je bent goed aan het meewerken!

<u>Fase 4.3: Taak 3</u> (nodig: rietje, latje, wit papier met zwarte streep van 15 cm: A, wit papier met zwarte streep van 80 cm: B)

Je toont wat een centimeter is op een latje.

Je toont een rietje.

a) Je toont het wit papier met de zwarte streep van 15 cm: A.

“Hoe lang denk je dat deze streep is in centimeters?” *noteer*

“Hoeveel rietjes zouden er passen in de lengte van de zwarte streep?” *noteer*

b) Je toont het wit papier met de zwarte streep van 80 cm: B.

“Hoe lang denk je dat deze streep is in centimeters?” *noteer*

“Hoeveel rietjes zouden er passen in de lengte van de zwarte streep?” *noteer*

<u>Fase 4.4: Taak 4</u> (nodig: rietje, latje, wit zwart bedrukt papier met zwarte streep van 25 cm: C, grijs bedrukt papier met zwarte streep van 85 cm: D)

Je toont wat een centimeter is op een latje.

Je toont een rietje.

a) Je toont het bedrukt papier met de zwarte streep van 25 cm: C.

“Hoe lang denk je dat deze is in centimeters?” *noteer*

“Hoeveel rietjes zouden er passen in de lengte van de zwarte streep?” *noteer*

b) Je toont het bedrukt papier met de zwarte streep van 85 cm: D.

“Hoe lang denk je dat deze is in centimeters?” *noteer*

“Hoeveel rietjes zouden er passen in de lengte van de zwarte streep?” *noteer*

Fase 4.5: Taak 5 (nodig: paperclip, latje, fotokader van 18 cm, wit touw van 80 cm)

Je toont wat een centimeter is op een latje.

Je toont een paperclip.

a) Je toont de fotokader van 18 cm.

   "Hoe hoog denk je dat het glas in deze fotokader is in centimeters?" *noteer*

   "Hoeveel paperclips zouden er passen in de hoogte van het glas van de fotokader?" *noteer*

b) Je toont het witte touw van 80 cm.

   "Hoe lang denk je dat deze is in centimeters?" *noteer*

   "Hoeveel paperclips zouden er passen in de lengte van het touw?" *noteer*

Fase 4.6: Taak 6 (nodig: paperclip, latje, gom van 5 cm, riem van 80 cm)

Je toont wat een centimeter is op een latje.

Je toont een paperclip.

a) Je toont de gom van 5 cm.

   "Hoe lang denk je dat deze is in centimeters?" *noteer*

   "Hoeveel paperclips zouden er passen in de lengte van de gom?" *noteer*

b) Je toont de riem van 80 cm.

   "Hoe lang denk je dat deze is in centimeters?" *noteer*

   "Hoeveel paperclips zouden er passen in de lengte van de riem?" *noteer*

Fase 4.7: Taak 7 (nodig: latje, potlood, rol tape)

Je toont wat een centimeter is op een latje.

Je geeft de rol tape.

a) "Plak met de tape een lijn van 10 cm op de bank/tafel zonder een meetlat te gebruiken." *Laat deze plakken tot dat het kind de kamer heeft verlaten, meet dan hoe lang de lijn effectief is en noteer*

b) "Plak met de tape een lijn van 70 cm op de bank/tafel zonder een meetlat te gebruiken." *Laat deze plakken tot dat het kind de kamer heeft verlaten, meet dan hoe lang de lijn effectief is en noteer*

Fijn dat je zo je best doet!

<u>Fase 4.8: Taak 8</u> (nodig: latje, touwen: 10 cm (grijs), 15 cm (roze), 5 cm (geel), 20 cm (groen), 70 cm (bruin/zeemanskoord), 60 cm (rood), 65 cm (paars), 55 cm (blauw))

Je toont wat een centimeter is op een latje.

a) Je legt de volgende touwen op een rij op deze volgorde van links naar rechts (volgens jouw aanzicht): grijs, roze, geel, groen
"Kijk even goed naar deze touwen, welke van deze is 10 cm lang?"
noteer

b) Je legt de volgende touwen op een rij op deze volgorde van links naar rechts (volgens jouw aanzicht): bruin, rood, paars, blauw
"Kijk nu even aandachtig naar deze touwen, welke van deze is 70 cm lang?" *noteer*

Participantnummer:……………

Geboortejaar:……………………..

Geslacht: ○ M ○ V ○ X

Eventuele comorbiditeit(en):

………………………………………………………………………………………………………

<u>4.1</u>

a) ………………………………..
b) ………………………………..

<u>4.2</u>

a) ………………………………..
b) ………………………………..

<u>4.3</u>

a) ………………………………..
b) ………………………………..

<u>4.4</u>

a) ………………………………..
b) ………………………………..

<u>4.5</u>

a) ………………………………..
b) ………………………………..

<u>4.6</u>

a) ………………………………..
b) ………………………………..

<u>4.7</u>

a) ………………………………..
b) ………………………………..

<u>4.8</u>

a) ………………………………..
b) ………………………………..

Appendix B

Informed Consent

Geïnformeerde toestemming

Titel van het onderzoek:
Schattingsvaardigheden bij kinderen met DCD.

Naam + contactgegevens promotor en onderzoeker:
Promotor
Reynvoet Bert, bert.reynvoet@kuleuven.be

Onderzoeker
Hufkens Joke, joke.hufkens@student.kuleuven.be

Doel en methodologie van het onderzoek:
In dit onderzoek worden er schattingsvaardigheden afgenomen via enkele vragen die mondeling en individueel dienen beantwoord te worden. We gaan voorwerpen tonen van verschillende lengtes. Bij elk voorwerp wordt gevraagd om te schatten hoe lang het voorwerp is in centimeters evenals "Hoeveel paperclips passen er in de lengte van dit voorwerp?" Er worden met andere woorden enkel vragen gesteld over lengtes van voorwerpen.
Het Secundair Onderwijs Dominiek Savio te Hooglede-Gits stelt zich de vraag of kinderen met DCD hoeveelheden, tijd en afstand anders inschatten dan kinderen zonder DCD. Momenteel ontbreekt wetenschappelijke evidentie hiervoor. Daarom hebben wij besloten om dit te onderzoeken.

Duur van het experiment:
20-30 minuten

- We vragen graag nog enkele gegevens:
  Hoogste diploma ouder/voogd 1:
  Hoogste diploma ouder/voogd 2:

Gelieve onderstaande informatie te lezen en indien uw kind mag deelnemen onderaan te tekenen en terug aan de leerkracht te bezorgen.

- Ik begrijp wat van mijn kind verwacht wordt tijdens dit onderzoek.

- Ik weet dat mijn kind zal deelnemen aan volgende test:
  Een test rond schattingsvaardigheden.

- Ik weet dat er risico's of ongemakken kunnen verbonden zijn aan deelname:
  Geen risico's of ongemakken.

- Ikzelf of anderen kunnen baat bij dit onderzoek hebben op volgende wijze:
  Gegevens van dit onderzoek kunnen gebruikt worden voor verder onderzoek.

- Ik begrijp dat de deelname aan deze studie vrijwillig is. Ik heb het recht om de deelname op elk moment stop te zetten. Daarvoor hoef ik geen reden te geven en ik weet dat daaruit geen nadeel voor mij of mijn kind kan ontstaan.

  Ik kan ook ten allen tijde vragen om de verdere verwerking van de gegevens stop te zetten, en in voorkomend geval ook de reeds verzamelde data te wissen.

Ik begrijp dat in de context van dit onderzoek gegevens worden verzameld die volgens de Algemene Verordening Gegevensbescherming als bijzonder gevoelig worden beschouwd. Ik geef dan ook expliciet mijn toestemming om deze gegevens in de context van dit onderzoek te verzamelen.

- De resultaten van dit onderzoek kunnen gebruikt worden voor wetenschappelijke doeleinden en mogen gepubliceerd worden. Mijn naam of de naam van mijn kind worden daarbij niet gepubliceerd, anonimiteit en de vertrouwelijkheid van de gegevens is in elk stadium van het onderzoek gewaarborgd.

- Ik wil graag op de hoogte gehouden worden van de resultaten van dit onderzoek. De onderzoeker mag mij hiervoor contacteren op het volgende e-mailadres:

- Voor vragen evenals voor de uitoefening van mijn rechten (inzage gegevens, correctie ervan,…) weet ik dat ik na deelname terecht kan bij:
  Hufkens Joke, via mail: joke.hufkens@student.kuleuven.be

- Voor eventuele klachten of andere bezorgdheden omtrent ethische aspecten van deze studie kan ik contact opnemen met de Sociaal-Maatschappelijke Ethische Commissie van KU Leuven: smec@kuleuven.be

Ik heb bovenstaande informatie gelezen en begrepen en heb antwoord gekregen op al mijn vragen betreffende deze studie. Ik stem toe om deel te nemen.

Datum:

Naam en handtekening ouder (Naam en handtekening kind) Naam en handtekening onderzoeker