Navigating the Challenges of Writing: A Narrative Study on the User Acceptance and Potential Use of an Assistive Device for Children with Motor Impairments

Antony Shruti Predhep

Rehabilitation Sciences
School of Physical and Occupational Therapy
Faculty of Medicine and Health Sciences
McGill University, Montreal
April 2023

A thesis submitted to McGill University in partial fulfillment of the requirements of the degree of Master of Science in Rehabilitation

Abstract

Writing is an essential skill for self-expression and communication in childhood. However, some children struggle to develop this skill due to gross or fine motor impairments, or developmental disabilities caused by neurological disorders. Such impairments can make it difficult for children to effectively use or grip the pencil, negatively affecting their writing skills. To overcome this issue, assistive technology (AT) has been employed as an intervention allowing children to meet their writing goals. In this context, the Handwriting Assistive Device (HAD) has been recently designed and developed to facilitate writing for children with writing difficulties.

The objectives of this master's thesis were to explore the perspectives of parents of children with motor impairments, as well as of individuals with motor impairments, on the HAD by outlining their needs and priorities regarding writing performance and its potential impact on everyday lives. Their perspectives may be influenced by their earlier experiences with AT and by their varied social and environmental conditions, resulting in differing experiences for writing. For these reasons, it was valuable to consider the perspectives of parents of children with motor impairments and of individuals with motor impairments in determining the potential impact of the HAD among children with writing difficulties. Semi-structured interviews were conducted with eleven participants divided into two groups: (1) parents of children with motor impairments (n = 9); and (2) adults with motor impairments (n = 2). These interviews were guided by the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Human Activity Assistive Technology (HAAT) models within these three contexts: (1) written performance, (2) social context, and (3) user acceptability and accessibility. Interviews were then transcribed and analyzed using an inductive thematic method.

The study's findings suggested a positive outlook from parents on the design and potential impact of the HAD. Parents reported that the HAD could be used as an alternative solution to digital AT and believe it could positively impact their children's written performance, instill confidence, and promote autonomy. Further, they added that it could affect their children's identity either positively or negatively. They also recommended that a compact and colourful design could make the HAD more engaging and approachable in home and classroom settings.

These results can inform further research and development in the engineering and rehabilitation research communities for a range of pediatric populations. Overall, the study concludes that HAD has the potential to be integrated into socially inclusive instruction and early intervention models targeting writing skills.

Abrégé

L'écriture est une compétence essentielle pour l'expression et la communication pendant l'enfance. Cependant, certains enfants ont du mal à développer cette compétence en raison de déficiences au niveau de la motricité grossière ou fine ou de troubles du développement causés par des troubles neurologiques. Ces incapacités peuvent empêcher les enfants d'utiliser ou de tenir efficacement le crayon, ce qui affecte négativement leurs compétences en matière d'écriture. Pour résoudre ce problème, la technologie d'assistance (TA) a été utilisée comme une intervention permettant aux enfants d'atteindre leurs objectifs en matière d'écriture. Plus récemment, les technologies d'assistance numériques (ordinateurs, tablettes, etc.) ont progressivement remplacé l'écriture traditionnelle au crayon et au papier. Dans ce contexte, un appareil d'aide à l'écriture (AE) a été récemment conçu et développé pour faciliter l'écriture des enfants rencontrant des difficultés d'écriture.

Les objectifs de ce mémoire de maîtrise étaient d'explorer les perspectives, aue sujet de l'AE, de parents d'enfants avec déficiences motrices, et aussi d'adultes avec déficience motrice, en décrivant leurs besoins et priorités concernant la performance d'écriture et son impact potentiel sur leur vie quotidienne. Les perspectives de ces deux groupes peuvent différer non seulement en fonction de leurs expériences antérieures en matière de TA, mais aussi en fonction de leurs conditions sociales et environnementales variées, ce qui se traduit par des expériences diversifiées en matière d'écriture. Pour ces raisons, il est utile de tenir compte du point de vue des parents d'enfants avec déficiences motrices et aussi de personnes avec déficiences motrices, pour déterminer l'impact potentiel de l'AE chez les enfants ayant des difficultés d'écriture. Des entretiens semi-structurés ont été menés avec onze participants répartis en deux groupes : (1)

parents d'enfants avec déficience motrice (n = 9) et (2) adultes avec déficience motrice (n = 2). Ces entretiens ont été guidés par la théorie unifiée de l'acceptation et de l'utilisation de la technologie (UTAUT) et le modèle de la technologie d'assistance et de l'activité humaine (HAAT) dans ces trois contextes : (1) la performance en écriture, (2) le contexte social, et (3) l'acceptabilité et l'accessibilité pour l'utilisateur. Les entretiens ont ensuite été transcrits et analysés à l'aide d'une méthode thématique inductive.

Les résultats de l'étude suggèrent un point de vue positif des parents sur la conception et l'impact potentiel de l'AE. Les parents ont indiqué que l'AE pourrait être utilisé comme une solution alternative à la TA numérique et pensent qu'il pourrait avoir un impact positif sur les performances en écriture de leurs enfants, leur inspirer confiance et promouvoir leur autonomie. En outre, ils ont ajouté qu'il pourrait avoir un impact positif ou négatif sur l'identité de leurs enfants. Ils ont également recommandé qu'un design compact et coloré rendrait l'AE plus attrayante et plus accessible à la maison et dans les salles de classe.

Ces résultats peuvent contribuer à la poursuite de la recherche et du développement dans les domaines de l'ingénierie et de la réadaptation pour un large éventail de populations pédiatriques. Dans l'ensemble, l'étude conclut que l'AE peut être intégrée dans des modèles d'enseignement et d'intervention précoce socialement inclusifs ciblant les compétences en écriture.

Acknowledgements

This thesis would not have been possible without the grace of almighty God and the support of several people throughout my academic life.

First and foremost, I would like to express my deepest gratitude towards my supervisor, Dr. Philippe Archambault, who has supported me with his constant patience and guidance throughout the completion of my thesis. The past 3.5 years have been truly a life-changing experience for me, which would not have been possible without his unwavering support throughout the journey. Be it in selecting the research topic on assistive technology, designing the study, recruiting the participants, analyzing the data or thesis writing, I can't thank him enough for being such an excellent mentor. I especially appreciate him for being amazingly understanding and kind during my extra tough times and throughout the pandemic.

Second, I would like to extend my sincere thanks to Dr. Alexandre Campeau-Lecours and his team for offering me the opportunity to work on his design prototype – The Handwriting Assistive Device. I am also extremely grateful to Dr. Véronique Flamand for standing beside me as my co-supervisor for the past two years. She brought her invaluable expertise and helped in making my study accurate and valid. I would also like to thank Dr. Dana Anaby for her constructive advice during my protocol stages and Abdelmonem Farhat for helping me shape my qualitative analysis.

Next, a big thanks to Farnaz, Vira, Martha, Adriana, Marc, Rachel, Naomi, Alissa and all the amazing people who touched my life at the School of Physical and Occupational Therapy (SPOT), Montreal Neurological Institute (MNI), Jewish Rehabilitation Hospital (JRH) and McGill University. Also, this thesis would not be possible without the financial support from my supervisor,

bursaries and scholarship through SPOT and SSAO, and a special thanks to my financial counsellor, Alison Mackay.

Finally, I would like to express my sincere gratitude to my Amma and Appa, who encouraged me to chase my dreams even though life wasn't easy for them for the past three years. Thank you, amma, for lending me your wings and letting me fly and thank you, appa for inspiring me every day. I am indeed grateful for their unconditional support and continued prayers throughout my academic endeavours. I would also like to thank my brother, mama, athai, chithappa, divakar and all my amazing friends from India and Montreal for believing in me and showering me with unconditional love and support.

Contributions of author

The study described in this thesis was designed and completed by Antony Shruti Predhep under the supervision of Dr. Philippe Archambault, Dr. Véronique Flamand and the support of the supervisory committee: Dr. Dana Anaby and Dr. Alexandre Campeau-Lecours.

The thesis includes one manuscript on the usability of an assistive device for writing in children with writing difficulties. Antony Shruti Predhep carried out qualitative analysis under the guidance of Philippe Archambault. This chapter was written by Antony Shruti and subsequently reviewed by Philippe Archambault and Véronique Flamand.

Abbreviations

AT	Assistive Technology
CEGEP	College of General and Professional Teaching
COVID 19	Coronavirus disease of 2019
CP	Cerebral Palsy
CRIR	The Centre for Interdisciplinary Research in Rehabilitation
DCD	Developmental Coordination Disorder
DRHP	Diagnosis and Remediation of Handwriting Problems
ETCH	Evaluation Tool of Children's Writing
HAAT	Human Activity Assistive Technology
HAD	Handwriting Assistive Device
HWII	Here's How I Write
ISO	International Standards Organization
MHA	Minnesota Handwriting Assessment
ROM	Range of Motion
STT	Speech-To-Text software
UTAUT	Unified Theory of Acceptance and Use of Technology
VMI	Visual Motor Integration

List of Figures

List of Tables

Table of Contents

1 CHAPTER 1: INTRODUCTION

1.1 Rationale

Writing is a tool for communication – a way to convey our thoughts, feelings and ideas to others. It is required not just for communication but also critical for an individual's literacy (Cahill, 2009) That said, the development of the writing process in a child's early years can determine success in later life. Moreover, it is more than a motor skill – for example, it elicits greater activation in brain areas than in other activities (James & Engelhardt, 2012). However, children with motor impairments, neurological impairments, learning disabilities and developmental disorders often struggle to write and expend time and effort to write legibly (Oskoui, Coutinho, Dykeman, Jette, & Pringsheim, 2013). Nevertheless, learning to write appears to be a challenge for these children, so handwriting interventions (Denton, Fletcher, Anthony, & Francis, 2006) have been implemented in the past to mitigate their writing difficulties. But due to their diverse needs and demands in writing, the effectiveness of these interventions was similar among typically developed children and children with writing difficulties (Feder & Majnemer, 2007; Kadar et al., 2020).

A complementary option to clinical interventions is implementing assistive technologies (AT) to improve writing and participation and promote functional independence (Parette & VanBiervliet, 1990; Swinth & Case-Smith, 1998). Assistive technology is defined as "any item, piece of equipment or product, system whether acquired commercially off the shelf, modified or customized that is used to increase, maintain or improve functional capabilities of individuals

with disabilities ("Assistive Technology Act," 2004); or “any product, instrument or technology adapted or specifically designed for improving the functioning of a disabled person” ("UNICEF, WHO," 2018). Both of these definitions focus exclusively on technology or an instrument, so for our understanding of AT, we will use the term “assistive devices” throughout the thesis study, wherever it suits the context. In recent decades, there has been a dramatic shift in the use of AT, which has improved their accessibility and enhanced participation. These children may begin with low technology assistive devices, such as adaptive pencil grips or smooth writing pens, to help them learn cause and build foundational skills for writing or future assistive devices. Often low-tech solutions may not be motivating, or the children may not have the adequate fine motor skills to access them (Cole & Swinth, 2004). In considering the limitations of the low-tech devices, electronic communication aids, such as a keyboard, portable word processor, speech-to-text (STT) software, and computer-based systems, can be useful. In recent years, computer-based systems have become popular and a preferred choice to more expensive text-generating devices. Computers with or without specialized software provide multiple means of communication in written production, self-expression, and completing school and work-related tasks with greater degrees of independence. It can be a powerful instructional tool, more portable, work faster, and have a more socially acceptable appearance; despite their good potential, it replaces writing entirely (Longcamp, Zerbato-Poudou, & Velay, 2005). Beyond the physical components of computer, writing is a cognitive process that encompasses brainstorming or generating ideas, composing and organizing ideas, editing, and finally, producing it (Longcamp et al., 2005; Ose Askvik, van der Weel, & van der Meer, 2020; Osugi et al., 2019). However, keyboards bring in

different cognitive functions, as it all takes to press the right key on the keyboard, which affects the benefits of learning (through writing).

Given the important impact that AT have on traditional writing, there is a need for a writing assistive aid to support and maximize the children's writing skills with writing difficulties. It is important to remember that these children are in the process of building experiences that affect their developing brain and, therefore, must learn differently than typically developed children.

Our current study proposes a Handwriting Assistive Device (HAD) as a high-tech assistive device and intervention for children with writing difficulties due to motor impairments during their formal years of instruction. The overall aim of this study was to explore the HAD - as an intuitive and adaptive tool in a natural context, involving the potential relationship between the writing process and writing performance.

Our initial objective was to examine the effectiveness of the HAD in children with CP. The data collection involved the testing and validation of the HAD, requiring in-person sessions with children. However, the COVID-19 pandemic introduced barriers to this objective. Due to restrictions in recruitment and physical proximity, this meant redesigning the research study so that it did not require in-person sessions. Furthermore, an important goal in intervention and in assistive devices involve a parent-directed approach, a key concept when dealing with children with writing difficulties (Kaminski, Valle, Filene, & Boyle, 2008). Generally, parents support their children by monitoring their developmental growth and are tasked with structuring their learning environment, such as overseeing their daily writing tasks, helping with their homework and following the teacher's plans. It is to be assumed that parents are actively engaged in their child's

writing development, which Alberta Education defines as "a parent-directed approach to educating a student […] at home or elsewhere in which [parents] are responsible for making all decisions" ("Government of Alberta," 2020). Thus, it is significant to obtain parents' opinions, to understand the child's experience and participation in writing and AT, in adopting the HAD and its possible social limitation.

1.2 Aim and research objectives

The aim of this study was to explore the perceptions of both parents of children and individuals with motor impairments, specifically in the domain of writing, regarding the Handwriting Assistive Device (HAD) and its potential impact on the writing skills of children. The research objective was to examine the thoughts regarding the Handwriting Assistive Device of both parents of children with motor impairments and of individuals with motor impairments, particularly in relation to the HAD's potential impact on: (1) writing performance, (2) social context, and (3) user acceptability and accessibility.

2 CHAPTER 2: BACKGROUND

2.1 Children with writing difficulties

Writing is a complex sensorimotor process as it integrates visual perception of the letters and words with the appropriate motor response. Motor impairments in children may affect writing in a variety of situations. It can be due to their limited range of motion, poor hand or finger control, decreased movement efficiency, fluctuating tone, reduced stability, low endurance and fatigue (Exner, 2006). Children with cognitive deficits may struggle to organize their thoughts or ideas for written communication, proper letter formation and basic punctuation mechanics. The child may also exhibit poor recognition memory to discriminate letters or numbers in different positions and environments, indicating visual-discrimination problems, problem-solving and judgement (Missiuna, Mandich, Polatajko, & Malloy-Miller, 2001). In addition, visual-sensory problems can also affect a child's handwriting (Gordon, Charles, & Steenbergen, 2006).

Consequently, writing difficulties in children can be caused by neurological impairments (Exner, 2006), cognitive deficits, including poor fine motor skills, low vision (Ghasia, Brunstrom, Gordon, & Tychsen, 2008), visual discrimination, imbalance in posture (Shumway-Cook, 2001), inability to integrate visual and motor functions, or a combination of these disorders. Evaluating the pediatric population with writing difficulties may help pinpoint children who may benefit from interventions to prevent the development of writing problems.

2.2 Disorders affecting writing skills

Around 10 to 30% of children struggle with writing (Karlsdottir & Stefansson, 2002) although clear prevalence in Canada has not been reported. Writing difficulties are most common among

children with (1) orthopedic conditions that restrict upper extremity function, (2) neurological disorders with significant loss of movement, severe spasticity, limited range of motion (ROM), and (3) neurodevelopmental disorders with poor motor planning and organization (Haberfehlner et al., 2011; Oskoui et al., 2013; Rocha & De Jesus, 2022).

Children who have orthopedic conditions, such as juvenile idiopathic arthritis (JIA), may experience significant limitations in their upper extremities, particularly in the wrist area, which can restrict their participation in various activities throughout their development. JIA refers to the heterogeneous group of idiopathic inflammatory arthritis conditions affecting children below sixteen years old, characterized by swelling of soft tissues, bone edema and erosion. Due to the limited range of motion and reduced grip force in wrist flexion, children motor impairments often experience restricted hand movements while writing (Haberfehlner et al., 2011). As a result of insufficient stability, these children are susceptible to muscle fatigue which can cause discomfort and pain.

Hand function can also be affected by neurological conditions such as cerebral palsy (CP) and dysgraphia, resulting in limitations in writing due to restricted or poorly controlled hand movements. Children with CP are caused due to a non-progressive lesion or injury of the brain. Brain injury may occur during the prenatal, perinatal and postnatal periods, but research indicates that 70% to 80% are perinatal in origin (Batshaw, 2007; Bax, 2005). Recent evidence has also suggested that CP can result from the interaction of multiple factors such as premature birth, maternal infection or health factors, low birth weight, exposure to damaging drugs and respiratory disorders, while in many cases, a single cause cannot be identified (Batshaw, 2007; Bax, 2005; Oskoui et al., 2013). They often exhibit hypertonia and muscle spasticity, which can

result in poor voluntary movement, limited coordination of fine motor skills and sensory dysfunction (Novak, Hines, Goldsmith, & Barclay, 2012; Ohgi, Takahashi, Nugent, Arisawa, & Akiyama, 2003). These children may experience additional problems, such as jerky or involuntary movements (Himmelmann, Hagberg, Wiklund, Eek, & Uvebrant, 2007). These involuntary movements can make grasping and manipulating objects challenging when carrying out daily activities such as writing, brushing teeth, or cutting with scissors. In addition, postural instability also affects the upper extremity function, as children with CP may rely on their upper extremities for support due to weakness in their trunk muscles (Shumway-Cook, 2001). Hence, it may compromise the efficiency of upper extremity function and prevent their ability to perform everyday tasks.

Children with dysgraphia have reduced fine motor skills and cognition-based difficulties, usually associated with multiple cortical and subcortical damage in the functional language regions. Their ability to write clearly is performed with great difficulty and often results in frustration. They usually have a problem with letter formation and slant, poor spacing between letters and words, excessive erasures, poor pencil grip, and letter and number reversals beyond the early stages of writing. Precision of movement may also be poor, due to low muscle tone, resulting in slow or illegible handwriting.

A type of neurodevelopmental disorder is developmental coordination disorder (DCD), often referred to as dyspraxia or problems in motor planning. For children with dyspraxia, they have problems with ideation – difficulty in generating ideas while they write or performing simple habitual tasks that seem to lack a goal (Rocha & De Jesus, 2022). Besides, the skills (such as writing and feeding oneself with utensils) that typically developed children attain easily can be

excessively challenging for children with dyspraxia. Moreover, these children are likely to have delays in meeting early developmental milestones, often avoiding motor challenges and may attempt to overcompensate for their behaviors, resulting in fatigue and frustration.

So, occupational therapists guide interventions by focussing on meaningful activities in the natural context, while providing a supportive and adaptive environment (Case-Smith & O'Brien, 2015). One such activity is writing – an essential and rewarding skill strongly linked to a child's health, development, and growth.

2.3 Difficulties in writing

Typically, the upper extremity must be strong and stable enough to grasp and manipulate the writing tools (Alaniz, Galit, Necesito, & Rosario, 2015) when preparing to write. However, children with writing difficulties can struggle in these areas, as they may not have adequate motor skills, decreased cognitive skills, and visual or sensory impairments (Rosenbaum et al., 2007). Writing difficulties such as poorly formed handwriting, longer movement time, longer tracing length, and uncoordinated movements with significant errors, including incorrect direction, position and strokes, affect as many as 81.3% of children with writing difficulties. Considering that, occupational therapists recommend digital aids such as laptops and tablets as a remedial or compensatory intervention for writing (Longcamp et al., 2005; Osugi et al., 2019). Even though it would be less demanding for these children, writing skills are needed throughout their childhood and adolescence, as it facilitates memory recall, encoding of new information, critical thinking, idea generation and organization.

2.4 Prerequisites for writing skills

The fundamental skills such as fine motor skills, visual perception and visual- motor integration is necessary for children before they can develop writing. These skills develop sequentially and are integrated into writing, influencing the children's overall growth and development.

2.4.1. Fine motor skills

To demonstrate legible handwriting, children should be able to control a writing instrument with speed and accuracy throughout the writing, requiring adequate fine motor precision, manual dexterity and in-hand manipulation. At the most basic level, grasping a crayon and executing the motor pattern depends on their fine motor skills.

Early childhood is a time of rapid improvement in fine motor skills and in-hand manipulation. Fine motor skills involve precision in grasping, manipulating, and releasing objects, and it plays a vital role in general human development and autonomy in everyday life (Dennis & Swinth, 2001; Schwellnus et al., 2012). While in-hand manipulation indicates that the isolated finger movements are well controlled and that the thumb quickly moves into opposition for writing. These skills also illustrate that the child accurately perceives the gentle force needed to modulate the pencil with fingers while writing (John & Renumol, 2018).

2.4.2. Visual perception

Visual perception allows the children to recognize the letters and numerals while identifying the specific characteristics and orientations. Understanding the perception enables them to process sensory information quickly and correctly, which helps to recreate and write it smoothly (Case-Smith & O'Brien, 2015). Children with poor perceptual function experience difficulties in tactile

perception, visuo-sensory processing, and kinesthesia, interfering with the accuracy and quality of the writing (Williams, 2002).

2.4.3. Visual motor integration

Visual Motor Integration (VMI) skills refer to the interaction of fine motor skills, visual skills and visual perception. Additionally, eye-hand coordination and attention are significant components of VMI; as it relates to the processing of visual input to guide hand movements in everyday activities such as grasping objects, playing instruments or writing. Furthermore, numerous studies also indicate that strengthening fine motor skills and VMI has enormously improved children's writing performance (John & Renumol, 2018; Kadar et al., 2020).

2.5 Grasp development

A child's development of hand function depends on adequate visual motor integration, sufficient postural balance, and cognitive development. The patterns of hand function include grasp, voluntary release, carry and more complex skills such as in-hand manipulation. These functions develop through childhood and continue into their adolescence year. A critical sequence in the development of hand function is using the grasp patterns before the emergence of the pencil grip.

Children must pass through several stages of grasp development for an adequate pencil grip. Research studies have also suggested a strong correlation between the pencil grasp and functional writing, especially the quality and speed of writing (Koziatek & Powell, 2003; Schwellnus et al., 2012; Ziviani & Wallen, 2006). Commonly, children learn various grasp patterns

from 18 months to 6 years of age, and it follows a predictable course for typically developing children, while it varies among children with impairment.

The different patterns that can be observed in typically developed children include:

2.5.1. Palmar supinate grasp

The child begins to grasp the crayon or pencil-like objects with it's whole palm, commonly developed from twelve to eighteen months.

2.5.2. Static tripod grasp

The static tripod grasp begins a mature grasp pattern, which develops between three to four years. The child will also exhibit the movement of their entire arm instead of their individualized finger movements.

2.5.3. Digital pronate grasp

Around the age of two to three-year-old, the child will begin to hold the crayon in a pronated fashion (slightly inward position). The thumb will be adducted in this grasp pattern, with distinct finger isolation and functionality.

2.5.4. Dynamic tripod grasp

The tripod grasp involves the thumb, index and middle finger in opposition, performing as a dynamic 'tripod' grasp, allowing precise and coordinated movements. It is mainly developed between the age of four to six-year-old.

Figure 1

Development of grasp pattern by age (Erhardt, 1994, p156)

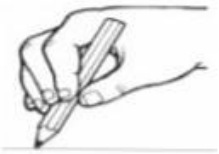
			
1-1½ years Palmar Supinate Grasp	2-3 years Digital Pronate Grasp	3½-4 years Static Tripod Grasp	4½-6 years Dynamic Tripod Grasp

Figure 1 (Erhardt, 1994) illustrates the patterns of grasp development for typically developed children until the age of six years. Additionally, the strength and refinement of grasp patterns develop throughout childhood, significantly increasing in children between four to five years old, and it continues to develop until they reach twelve years (Link, Lukens, & Bush, 1995; Mathiowetz, Wiemer, & Federman, 1986). However, children with delayed or limited grasp development will likely substitute other patterns such as alternating hands, transferring the writing tool from hand to hand and stabilizing the object on the table to reorient its position (Exner, 2006). Compared with the typically developed children, they exhibit alternative strategies for selecting and executing the grasp pattern needed during the task.

2.6 Grasp patterns – influencing factors

The grasp pattern development in young children follows an ideal course for typically developing children, which is influenced by a variety of factors such as age, society norms, cultural influences, and tool use.

2.6.1. Age, social and cultural factors

Age predicts the likelihood of the child holding a pencil. Typically, a child begins holding a pencil with a primitive grip between 18 and 30 months. Schwellnus reported in his study of typically developing children that by the age of seven, 90% adopted a dynamic tripod grasp. Initially, children learn the functional use of drawing – progressing from drawing circles to lines (K E Beery, 1997; Schwellnus et al., 2012). By controlling and manipulating the pencil, children can make letters and numbers. With practice in visually guiding their hand movement, their writing becomes automatic and continues to be refined for up to fourteen years (J. Ziviani, 1983).

Social and cultural factors likely influence the acquisition and use of hand function; therefore, the relevant factors are gender, cultural and socioeconomic status (Case-Smith & O'Brien, 2015). In particular, socioeconomic status and cultural factors may not affect the development of basic hand skills but can influence the acquisition and manipulation of objects and tool use. For instance, children living in poor and marginalized communities may not have the luxury to afford writing tools or toys that would directly or indirectly help their writing skills development.

Meanwhile, the tools specific to one cultural group influence their object manipulation skills (Chow, Henderson, & Barnett, 2001). To illustrate, eating food with utensils vary from chopsticks to spoons, while some culture has neither of them. Apparently, children who belong to that particular culture may not have the opportunity to develop tool-specific skills. As explained by Flynn and Whiten, the development of grasp pattern and manipulation skills doesn’t depend on the availability of objects; instead, it relies on good exposure to a variety of materials with an

opportunity to utilize them and repeated observation of such tools among adults and peers (Flynn & Whiten, 2008).

2.6.2. Tool use competence

Tool use plays a vital role in everyday life, and it's essential for children and adults to interact with the environment. These skills emerge concurrently with the grasp patterns and manipulation skills, as it allows them to hold the tool dynamically within their fingers. Initially, the child experiments with the tool by trying different grasp patterns, such as holding the pencil in either hand, with a fist or fingers, or at the base of the pencil. As their manipulation skills progress, they will develop a high level of attention, making their action more automated. Eventually, their writing performance will become smoother, faster and more precise with practice, resulting in proficient tool use (Jane Case-Smith, 2014).

In general, the child's grasp patterns and manipulation skills progress over time. Although, they are also determined by the various activities they are involved such as age, characteristics of the object and the tools used.

2.7 Prewriting skills of young children

Independent functioning of children in a school environment involves effective hand function and competence in fine motor skills. Children in kindergarten and elementary school engage in fine motor activities, primarily paper-pencil tasks. Between these ages, they begin by holding the crayon with a primitive grip to scribble and draw. Once they adopt a mature pencil grasp, their scribbles and drawings evolve into letter-like forms and a series of letters. Usually, they progress through the following stages of prewriting and handwriting: (1) controlled scribbles, (2) discrete

lines or symbols, (3) straight-line, (4) upper-case letters, (5) lower-case letters, numbers, and (6) words (Taras, Brennan, Gilbert, & Eck Reed, 2011).

Various factors are involved as to when a child is ready for formal handwriting instruction. Differing rates of maturity, environmental and cultural experiences and interest levels can influence their early attempts at writing. Researchers suggest that handwriting instruction can be postponed until after the child has mastered the nine shapes in the Beery Developmental Test of Visual-Motor Integration, indicating that they would be prepared for writing by six years old (K E Beery, 1997; Daly, Kelley, & Krauss, 2003; Weintraub N, 1998)

2.8 Domains of writing by hand

In evaluating the actual task of writing in children, the following areas need to be explored (Jane Case-Smith, 2014) : (1) kinesthetic, (2) kinetic components, (3) legibility components and (4) writing speed. These four features will help the therapists to uncover the problematic areas of the writing and set an individualized baseline for the writing interventions. It will help them to evaluate the handwriting assessment data to establish goals and appropriate activities for their next developmental plan as a context of intervention.

2.8.1. Kinesthetic components

Evaluating the different writing domains allows the therapist and clinicians to determine which tasks the child may be having difficulty with, and which could be addressed in a clinical intervention plan. It includes the following:

2.8.1.1. Stroke dimension

Stroke dimensions are often assessed in terms of their components – duration of the stroke, length, velocity and number of strokes (Mergl et al., 2004). It helps to distinguish between a stroke's spatial and temporal characteristics in a writing sample. Generally, children with writing difficulties may exhibit a large number of strokes with varied lengths in their writing. Rosenbaum et al. (2007) also found similar results among the dysgraphia population, reporting numerous strokes per letter compared to that of typically developed children.

2.8.1.2. Stroke consistency

Consistency refers to the orderly presentation and reproducibility of the stroke sequence in writing. However, the bottom line is invariance in writing. Besides, the direction of letter formation and kinesthetic perception may be the most critical elements in determining consistency (Alamargot & Morin, 2015). These elements can also influence the amount of pressure a writing tool applies.

2.8.2. Kinetic components

The most relevant kinetic component for handwriting is force, which can be subdivided in two components: grip force and axial force. Grip force refers to the pressure exerted radially on the writing tool, irrespective of the grasp patterns, which is an essential determinant of functional writing. Children may need sufficient strength to initiate the finger extension or the thumb opposition before a pencil grip, which may pose a challenge for children with writing difficulties. Schwellnus (2012) reported in his study of the hemiplegic cerebral palsy population that they had adopted a pencil grasp with decreased grip force and increased velocity. Axial force is the force

exerted perpendicular to the writing surface, also known as point pressure. It influences the children's grasp patterns – characterized by downward motion and pinching. Studies of handwriting show that poor writing is positively correlated to the increased variability in axial force (Harris, 1957; Lin, 2017). It explains how children with writing difficulties may be able to control pinching performance by using more downward force.

2.8.3. Legibility components

Legibility is generally quantified in four components: letter formation, alignment, size, spacing and slant. Of primary importance is whether what was written by the child can be read by the child, teacher or parent. The features that affect the legibility of writing are improper letterforms, poor leading in and leading out of letters, inadequate rounding of letters, incomplete closure of letters, and incorrect letter ascenders and descenders (Alston, 1991). Typically, legibility is determined by counting the number of readable words and dividing it by the total number of words in a writing sample. It helps the experts to assess the 'cut-off' for the legibility percentage in distinguishing between poor and good handwriting.

2.8.4. Writing speed

In addition to legibility, a child's writing rate is also detrimental to functional writing. Studies suggest that the handwriting speed in young children continues to increase gradually, becoming faster and automatic with each succeeding age (Zwicker & Hadwin, 2009). However, these studies' findings also indicate that the writing speed might not always be linear due to musculoskeletal anomalies in children, neurological disorders and writing conditions.

2.9 Handwriting assessments

It is essential to evaluate the children's handwriting and their underlying visuomotor skills to understand the letter formation process and provide remedial actions when needed. Reliable and valid assessments are critical to monitor their progress and eventual treatment effectiveness. Each of the following assessment tools possesses various features regarding the domains of handwriting tested (e.g., far point copying), age or grade of the child, script examining (e.g., cursive) and scoring procedures of the writing performance.

2.9.1. Standardized test for handwriting readiness

2.9.1.1. Visual-Motor Integration (VMI) screening test

A norm-referenced test can be employed to identify the visual motor abilities that affect children's writing performance (John & Renumol, 2018; Kadar et al., 2020). The Beery Developmental Test of Visual-Motor Integration is a standardized assessment used to measure individuals' visual and motor functioning. This test measures visual and motor function, targeting individuals aged between 2 and 100 years (Keith E Beery et al., 2010). It assesses their fundamental and developmental skills required for writing compared to the developmental norms based on age.

The ability to copy the first nine shapes of the Beery VMI test has been associated with writing readiness. These nine shapes of the Beery VMI test comprise vertical stroke, horizontal stroke, circle, cross, right oblique, square, left diagonal, oblique cross, and triangle (see Table 1)(Keith E Beery et al., 2010). In light of the above theory, Hepburn conducted a single case study on a child with William syndrome (Hepburn, Philofsky, John, & Fidler, 2005). He identified that her drawings

(such as triangles and houses) reflected letter structures (i.e., alphabet 'A') when writing was introduced to her. These findings suggest that the Beery test's first nine items could be used to screen children for writing difficulties.

Table 1

Initial nine items of the Beery VMI test (Keith E Beery et al., 2010)

Item Number	Item Description
1	Vertical line
2	Horizontal line
3	Circle
4	Vertical-Horizontal cross
5	Right oblique line
6	Square
7	Left oblique line
8	Oblique cross
9	Triangle

2.9.2. Standardized assessments for handwriting

2.9.2.1. Minnesota Handwriting Assessment (MHA)

The Minnesota Handwriting Assessment (MHA) was designed by Reisman (1993) as a norm-referenced test for children in grades 1 and 2. It assesses the quality and speed of the young children's handwriting by evaluating near copying tasks (i.e., copying from paper). As said, it's scoring depends on the handwriting quality (such as legibility, alignment, space, size and form of letters) and duration. The intra-rater reliability of MHA is 0.93 to 0.99, and the interrater reliability of MHA is 0.87 to 0.98, respectively.(Stiles, Sabbadini, Capirci, & Volterra, 2000)

2.9.2.2. Diagnosis and Remediation of Handwriting Problems (DRHP)

Stott, Moyes and Henderson (1987) developed the Diagnosis and Remediation of Handwriting Problems (DRHP), a criterion-referenced test used to identify and classify handwriting errors. It was designed for children who have at least two years of handwriting instruction (i.e., children above third grade). They will be instructed to write a story, guided by word cues to assess their handwriting performance. Indeed, the DRHP is "designed primarily to help teachers structure their observations on a child's writing". Scoring is based on the spacing, alignment, slant and deviation from the writing line. The interrater reliability of the DRHP is 0.61 to 0.65; suggesting that the low values may be due to the assessment's complex nature (Stott, Henderson, & Moyes, 1987).

2.9.2.3. Evaluation Tool of Children's Handwriting (ETCH)

The Evaluation Tool of Children's Handwriting (ETCH) was developed by Amundson (1995) to evaluate the legibility and speed of writing in children above six years. It was designed for children with learning disabilities, developmental delay and neuromuscular impairments. Domains of ETCH includes of writing letters, numerals, near point copying (i.e., copying from paper), far point copying (i.e., copying from board), dictation, and composing essays. Moreover, the scoring is based on letter formation, space, size, alignment, and writing speed. The interrater reliability coefficient of the ETCH is 0.84, while it varies among experienced and inexperienced raters (Amundson, 1995).

2.9.2.4. Here's How I Write: A child's self-assessment of handwriting and goal-setting tool (HWII)

Here' (HWII) was developed by Sarina Goldstand for children in the second through fifth grades. It is a criterion-referenced tool that uses the children's own writing samples to set goals for improvement. Interviews are conducted using picture cards to assess their handwriting performance, feelings about their handwriting and physical factors related to handwriting (Goldstand, Bissell, & Cermak, 2013)

2.10 Remediation strategies for handwriting

Children with writing difficulties must not avoid writing due to their handwriting, even if it may require increased amounts of energy and time compared to typically developing children (Medwell, Strand, & Wray, 2009). In that case, they should receive remedial strategies to improve their sensorimotor skills that would encourage writing. Accordingly, occupational therapists consult with students, teachers and parents to determine handwriting practice interventions and writing tasks. At least three modes of intervention have been described in the literature: (1) sensory-based training, (2) handwriting practice, and (3) keyboard-based strategies.

2.10.1. Sensory-based training

Sensory-based training is an intervention proposed to improve movement kinesthesis through training. Kinesthesis refers to the perception of body movements, detecting changes in body position and movement without relying upon information from the five senses. All sensory systems, including the proprioceptive, tactile, visual and auditory, can be accessed and reinforced within a handwriting intervention program. It is assumed that an improvement in kinesthesis will eventually lead to improved motor performance, including handwriting.

Children with writing difficulties who have experienced frustration with paper and pencil drills respond more favourably to handwriting instruction using a multisensory format. Favourably, Denton (2006) suggests that multisensory approaches in the therapeutic practice of handwriting motivate children, which has improved their writing performance.

2.10.2. Handwriting-based practice

In handwriting-based intervention, children receive treatment to help them form letters and self-correction, focusing on their cognitive skills. Notably, Berninger (2006) examined the children with a "handwriting club" intervention, designed with handwriting exercises such as writing their own name, composing stories, etc., to be involved as writers. These one-hour sessions were carried out twice per week over four months. There was a small intervention effect among children with writing difficulties, with an effect size of 0.32.

However, the interventions should allow handwriting practice for at least 20 sessions to be effective (Berninger et al., 2006). Due to the children's diverse needs and the effectiveness of intervention (involving a higher level of practice), it is crucial to create an inclusive environment with writing technologies that enables them to be better writers.

2.10.3. Keyboard-based strategies

In Canada, ninety-three percent of occupational therapists recommend keyboard-based strategies for children who experience handwriting difficulties. It allows the students to complete their assignments on time and even in everyday activities. The most recommended keyboard-based strategies are desktop computers, laptops, assistive software, alternative keyboards, and electric diaries. A survey was conducted to investigate the factors influencing a therapist's

decisions in recommending a keyboard intervention over others. The results revealed that economic status, equipment availability, and portability significantly impact the therapist's keyboard-based strategies (Freeman, Mackinnon, & Miller, 2005).

Even with the limited research (Freeman et al., 2005), the concerning factors that influence the occupational therapist's recommendations in children with writing difficulties are the portability of the technology, lack of support in schools, and therapists' technical expertise.

2.11 Available assistive technologies

Assistive technology (AT) can be used to improve the writing skills of children with difficulties, with a wide range of low to high-technology devices available for this purpose. It also promotes independence and reduces the impact of disability on individuals, families and society more broadly.

2.11.1. Low-tech assistive devices

Low-technology devices are inexpensive, easy to make and easy to obtain. These readily available devices change how children receive, interact and apply information in their everyday life, offering functional independence and opportunities for participation at home, school and in society. These devices include adaptive pencil grips, weighted pens, pencils and built-up form handles. Adaptive pencil grips in silica gel or other material (Figure 2 ("Grotto Grip,")) are extensively used in schools to hold the pen/ pencil with a correct posture. These are available in various sizes, shapes and textures, which could be changed based on the child's fine motor control skills. They help them with injury, muscle fatigue, weakness, and writing difficulties by improving or facilitating their writing instrument's grip. Apart from the pencil grips, weighted

pens and pencils (Figure 3 (Wanja, 2021)) are also available in the market. These heavier pens are recommended for children who have uncoordinated movement or similar conditions. Their ergonomic design provides excellent grip, comfort and efficiency. In addition, the weight of the pen can be adjusted based on the severity of the tremor.

Figure 2

GROTTO Grip Pencil Grasp Trainer ("Grotto Grip,") – an adaptive pencil grip designed to help individuals develop proper pencil grip.

Figure 3

Thixotropic™ Heavy Super Big Fat Weighted Pen – a specialized writing tool designed to assist individuals with motor impairments (Wanja, 2021)

2.11.2. High-tech assistive devices

More complex technology in writing also exists; to encourage engagement, self - expression and social participation. For example, McKenzie have designed a writing assist device comprising of a convex contour with stretchable clasps that secures the user's fingers, and an inclined channel that keeps the pen in place as shown in Figure 4 (McKenzie, Miller, Mosley, & Saathoff, 2008). The device's ergonomics enable a natural writing position, allowing the user to simply move the device while writing. However, it cannot adapt to the user's spasticity which poses as a limitation (McKenzie et al., 2008). Kotovsky (1998) have designed a tremor suppression method that uses a shock absorber. It creates the power that is 180 °, out of phase with the subject's tremor, to

suppress it. However, it makes solid contact with the subject's body and causes discomfort. Figure 5 depicts a drawing device for children with CP developed by Wu (Wu, 2003). However, due to its small range of motion could not target users with a movement disorder due to spasticity, spasms, and joint deformities. As shown in Figure 6, Kim have designed a glove-type assist device called GRIPIT for individuals suffering from spinal cord injuries (Kim, In, Lee, & Cho, 2017). The GRIPIT enables individuals to grasp a tool in a dynamic tripod grasp fashion with the help of an actuated tendon-driven mechanism. The individuals should manually apply force and adjust the grasp through a single wire. However, the participants insisted they would need a simplified GRIPIT assist device for future work (Kim et al., 2017). Also, a wide array of software applications is available for students to help with their writing, including letter formation, spelling and organization. For instance, speech recognition software converts speech into text with eight seven percent accuracy, and graphic organizers help children plan and organize their writing.

Figure 4

McKenzie's writing assist device – a writing tool for improving writing skills (McKenzie et al., 2008, p. 3)

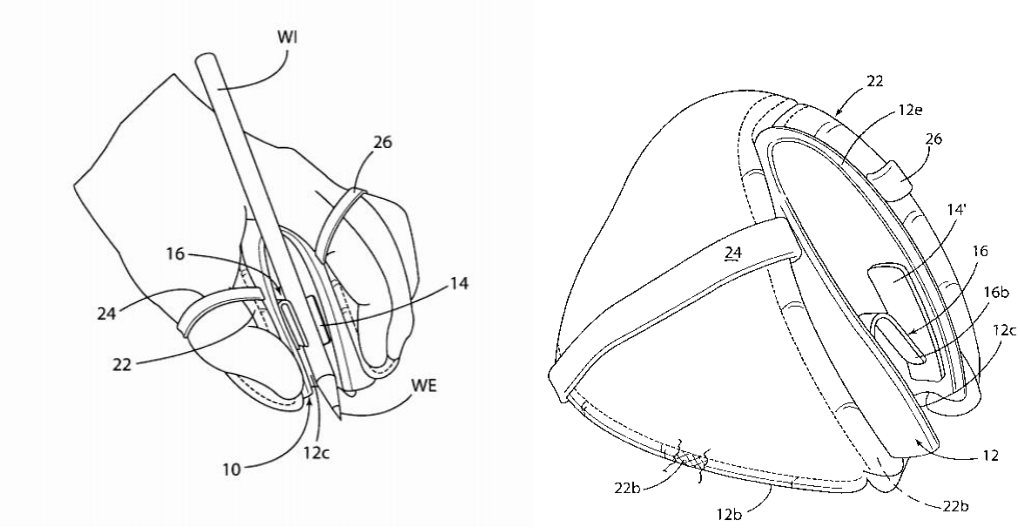
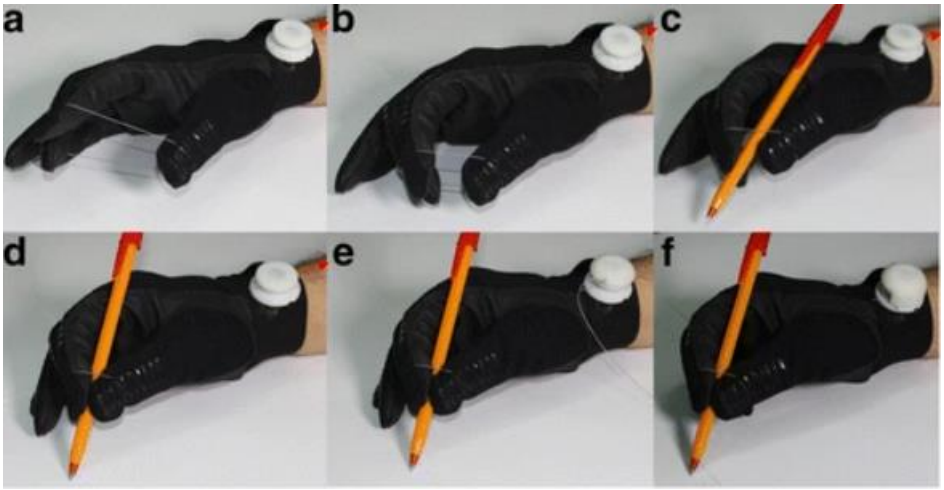


Figure 5

Assistive drawing device using hand-grip and arm support for individuals with motor impairments (Wu, 2003, p. 242)

Figure 6

GRIPIT hand assist device for improving writing skills (Kim et al., 2017, p. 7)



Despite the increasing range of assistive devices available with comparative portability and prices, research on their effectiveness is limited (Idor Svensson, 2021)

2.11.3. Assistive technology - recommendations

Therapists must carefully select the assistive technology that might work best for children with writing difficulties (Jane Case-Smith, 2014). They should evaluate their cognitive, physical, perceptual and sensory abilities to develop a sense of their strengths and weaknesses.

Apart from assistive devices, personal computers, tablets, handheld devices, and mobile phones are becoming more prevalent in school, home or work settings. Most children have some exposure to these devices by the time they enter school. These might be a flexible, powerful instructional tool and motivate children for their individualized learning while removing the social stigma of looking “different.” However, these digital devices replace traditional writing, which will affect the benefit of learning through writing (Longcamp et al., 2005).

So, young children with writing differences should be introduced to a progression of systems that follow their developmental and functional needs while supporting and maximizing their writing skills and performance.

2.12 The Handwriting Assistive Device – Instrumentation

A handwriting assistive device has been proposed and developed (Lemire, Laliberté, Turcot, Flamand, & Campeau-Lecours, 2019) to assist children with their writing in a traditional way. The HAD design comprises a five-bar mechanism with two degrees of freedom, a rotatable arm, a self-levelling pencil handle, and a writing base. A rotatable and self-articulated arm is attached to the end effector, which moves in a cartesian plane. The pencil handle has a convex contour

that securely grasps pens or crayons with a diameter of 8 to 20 mm, easily interchanged. The writing base includes a flat, smooth surface adapted to easily slide for writing while maintaining the pencil handle's constant orientation. Notably, rotatory dampers were added to the HAD joints, eliminating the hand tremors by absorbing them.

Figure 7

Prototype design of Handwriting Assistive Device (Lemire et al., 2019, p. 2)

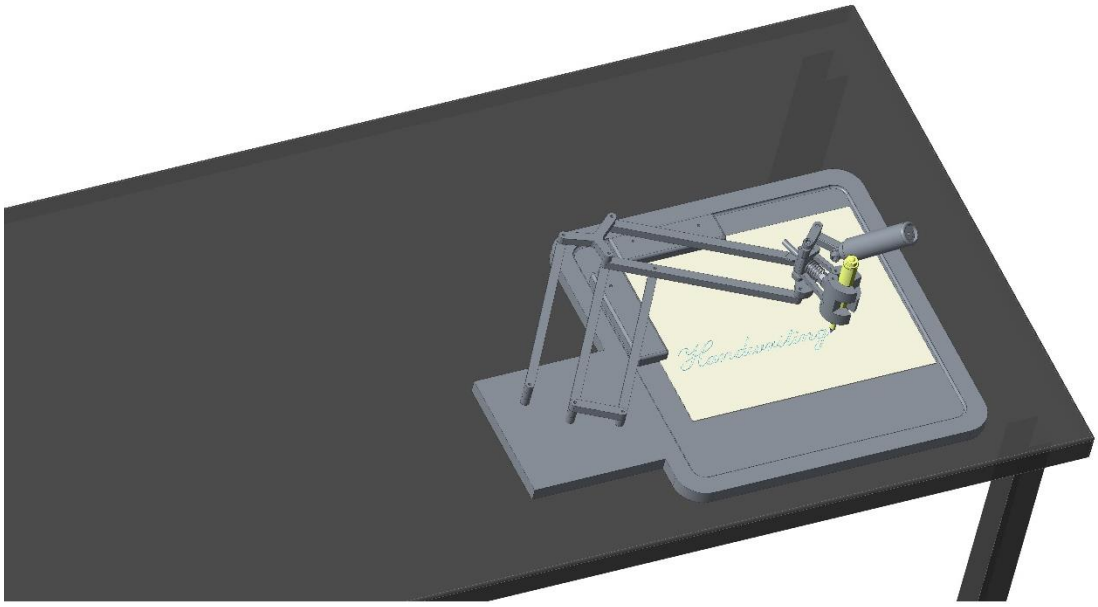
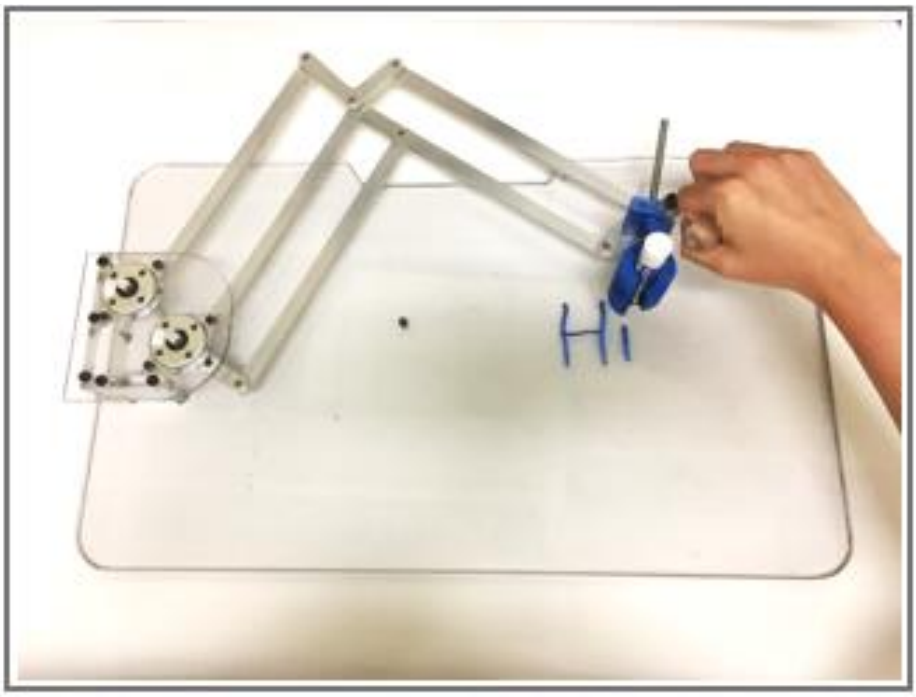


Figure 8

Developed prototype of the Handwriting Assistive Device



Overall, the HAD prototype assists the participant (1) in holding the pen with poor fine motor skills, (2) in providing an adaptive pencil handle with different shapes such as “T,” “L,” and sphere. It can also be customized according to the user’s grasp pattern, (3) having light and compact dampers. It targets participants with movement disorders by stabilizing their uncoordinated movements. On top of that, the HAD is purely mechanical (i.e., not motorized), making it autonomous and easy to use.

Furthermore, the HAD has been hypothesized to bring five specific aims: (1) a decrease in the movement time for writing tasks, (2) a reduction of the uncoordinated hand movements, (3) a reduction in the number of writing errors, (4) a more stable grasp posture and orientation, and (5) a smooth movement.

2.13 Assistive devices usability and acceptability

Assistive devices aim to provide autonomy for children with diverse needs, by expanding their functional abilities to promote quality of life, independence and accessibility. Therefore, to make the HAD more accessible to children with writing difficulties, it is necessary to consider aspects such as usability and acceptability, as discounting those aspects might lead to the abandonment of the HAD and lose its purpose altogether. Factors that may influence the abandonment of the use of assistive device may include : acceptance of difficulties or disability (Phillips & Zhao, 1993), acceptance of technology (Alomary & Woollard, 2015), social support or stigma (Pape, Kim, & Weiner, 2002), provider failure to consider user's opinion (Alomary & Woollard, 2015; Phillips & Zhao, 1993) and increased care costs. In this sense, a better understanding of factors such as usability and user acceptability is critically needed to realize the full potential of the assistive device, enhance user's experience and reduce device abandonment (Pape et al., 2002; Phillips & Zhao, 1993)

Usability of a device is defined as the effectiveness, efficiency and satisfaction of specific users involved in using a device or a product in a specific environment for a specific purpose ("The International Organization for Standardization," 1999). In terms of assistive devices, ISO defines effectiveness as the "accuracy and completeness with which users achieve specified goals", efficiency as the "resources used in relation to the results achieved" and satisfaction as the "extent to which the user experience meets the actual needs and expectations of the users". Thus, the present study had to consider the usability of the device, as the user's level of functioning with it depends on the assistive device's effectiveness, efficiency and the level of satisfaction. Therefore, considering the device's usability, it is significant to find out what impact

the HAD might have on children's participation in writing tasks, its accessibility, and its possible limitations concerning psychological and social factors.

A complementary approach to understand user acceptability is through the Unified Theory of Acceptance and Use of Technology (UTAUT). The UTAUT is a model to understand and assess a user's intention regarding a specific technology or device, thus allowing one to examine the critical influences on acceptance in a specific context. This model presents four core constructs: performance expectancy, effort expectancy, social influence and facilitating conditions, which determine the users' behavioural intentions influenced by gender, age, experience and voluntariness of use (Venkatesh, Morris, Davis, & Davis, 2003). Therefore, the UTAUT model can be used to assess the adoption and acceptance of HAD as it will explore the individual's thoughts on the ease of use, social influence and potential impact of HAD on their writing experience.

3 CHAPTER 3: Manuscript for submission

Navigating the Challenges of Writing: A Narrative Study on the User Acceptance and Potential Use of an Assistive Device for Children with Motor Impairments

Antony Shruti Predhep [1,2]

Philippe Archambault [1,2]

Véronique Flamand [3,4]

[1] School of Physical and Occupational Therapy, McGill University, Canada

[2] Center of Interdisciplinary Research in Rehabilitation of Greater Montreal (CRIR), Canada

[3] Centre for Interdisciplinary Research in Rehabilitation and Social Integration, CIUSSS de la Capitale-Nationale, Canada

[4] Department of Rehabilitation, Université Laval, Quebec City, Canada

Abstract

Writing is a foundational skill to an individual's development, particularly for children, as it influences academic success, self-esteem and confidence. Assistive technology (AT) should be considered to ensure the adequate development of writing skills. Despite advances in digital AT, writing by hand is considered more effective for learning than typing, as it promotes the overall child's development. Building on the benefits of writing, a new assistive device - the Handwriting Assistive Device (HAD), has been designed and developed to reduce spasticity and support traditional writing in children with writing difficulties. Furthermore, it is essential to consider the perspective of both parents of children with writing difficulties, and of individuals with writing difficulties to determine whether HAD can be effective for pediatric population. The aim of this study was to explore the perception of the HAD for parents of children with motor impairments and individuals with motor impairments on written performance, social context, user acceptability and accessibility, by conducting semi-structured interviews. An interview guide was developed based on the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Human Activity Assistive Technology (HAAT) model. The study addressed the HAD's potential impact within these three contexts: (1) written performance, (2) social context, and (3) user acceptability and accessibility. Participants reported a positive impact on written performance and other writing factors. They also reflected on the effect of the HAD on children's identities. Future studies are needed to evaluate the effectiveness of the HAD in real-world environments, including children's experiences with the device.

Keywords: children, writing difficulties, assistive technology, writing, UTAUT, qualitative research.

3.1 Introduction

Learning how to write is a complex process, as it requires the integration of fine motor, visuo-perceptual, sensory and cognitive skills, as well as the execution of components such as grip, in-hand manipulation, posture and sustained attention (Donica, Goins, & Wagner, 2013). Similarly, writing acquisition typically spans several years in an individual's life and co-occurs with a child's development. Nonetheless, writing is still challenging among children with writing difficulties, possibly due to orthopedic, neurological or neurodevelopmental disorders (Haberfehlner et al., 2011; Oskoui et al., 2013; Rocha & De Jesus, 2022). Specifically, children with CP, DCD and dysgraphia struggle with writing and often have compromised social participation, quality of life, independence, and academic performance, eventually affecting their overall development. Further, they may struggle to hold writing tools, inability to write as quickly as typically developed children, have a harder time planning or executing their ideas and produce illegible texts (Rocha & De Jesus, 2022; Rosenbaum et al., 2007; Schwellnus et al., 2012). These experiences discourage the children from practicing the necessary skills to acquire fluent handwriting, making them refuse writing altogether. Nevertheless, it is evident that these children need interventions to promote and support the development of foundational skills contributing to their writing skills during the early years of formal instruction.

Clinicians such as occupational therapists work with these children and review the components of handwriting by focusing on the child's interaction, environment and the demands of writing. They offer various approaches to improve writing while focusing on their remediating potential causes of writing or on the activity of handwriting itself. However, some difficulties still persist, and then the need for interventions such as remediation strategies or AT is recommended

(Denton et al., 2006; Osugi et al., 2019). While digital AT has become increasingly prevalent among children with writing difficulties in recent years, it is important to note the role of the physical act of handwriting in the nervous system's development (Longcamp et al., 2005). Indeed, evidence suggests significantly increased brain activity during handwriting due to its temporal and spatial components not being observed during typing. This supports the argument that handwriting involves intricate finger movements and shaping each letter, while typing is a series of repetitive movements providing less kinesthetic information (Ose Askvik et al., 2020; Osugi et al., 2019). This is in line with Medwell's research study that without the actual physical act of writing, the memory and retention of typed words will be comparatively poorer (Medwell et al., 2009). Considering the positive impacts of handwriting on a child's development, there is a need for interventions in children with writing difficulties, such as with assistive devices, which can have a far-reaching impact on function and quality of life.

Assistive devices are designed to enable the function and usability of individuals that rely on those devices. According to the International Standards Organization (ISO), a product's usability is "the extent to which a system, product or service can be used by specific users to achieve specified goals with effectiveness, efficiency and satisfaction in a context of use" ("The International Organization for Standardization," 1999). Assistive devices that focus on writing can be consistently provided to children with writing difficulties to increase their independence and age-appropriate function. Thus, the current study focuses on a Handwriting Assistive Device (HAD) that has been developed to assist children with fine motor impairments in their writing in a traditional way (Lemire et al., 2019). The HAD is a mechanical aid comprising a rotatable arm, a self-levelling pencil handle and a writing base. It has been designed to assist the children in

holding the pencil straight, as the arm moves smoothly around by providing balance. According to the children's grasp pattern, it has also been provided with an adaptive pencil handle in different shapes such as "T," "L," and sphere. In addition, it also has light and compact dampers that can be adjusted to limit the effects of uncoordinated movements. It, therefore, makes the HAD an autonomous assistive device for children with motor impairments that directly underpin handwriting.

Moreover, both the research and rehabilitation settings have highlighted the importance of understanding the parents' perspectives on children's learning ("Government of Alberta," 2020; Ulferts, 2020). It is essential to understand the parent's thoughts, as they have a collective responsibility for their children, influence their children's identity and play an active role in their children's lives. Thus, this study aimed to explore and investigate parental and individual views about the HAD for children with writing difficulties due to motor impairments.

3.2 Methods

3.2.1. Study design

A qualitative narrative research design was employed in this study, to explore participants' experiences with writing and AT as well as their opinions on the prospective use of the HAD and its potential impact on writing skills (Clandinin, 2000; Creswell, 2013; Riessman, 2008). The study included two groups of participants: (1) parents of children with motor impairments who reported on their children's writing, AT and potential impact of the HAD on quality of life; and (2) adults with motor impairments who recounted their experiences as a result of their neurological conditions and the influences that the HAD could have had in their childhood.

3.2.2. Participants

The study was approved by the Ethics Board Committee (project number: MP-50-2022-1263) of the Centre for Interdisciplinary Research in Rehabilitation of Greater Montreal (CRIR) – two approaches were used for recruitment.

In the first approach of the recruitment process, the clinical research coordinator from the Layton-Lethbridge-Mackay Rehabilitation Center (MAB, Montreal, Canada) identified seven potential participants by searching their clinical administrative database and reaching out to potential families who had attended their summer camps. One of the researchers (ASP) then contacted them to evaluate whether they met the inclusion criteria through phone calls and emails. Out of them, only one participant consented to participate in the study. The remaining individuals or families did not meet the eligibility criteria, were not interested in the study or had limited availability due to scheduling conflicts. A second approach was to reach out to potential participants through social media. The study was advertised on relevant Facebook groups, Instagram pages and subreddits to identify interested participants. Overall, fifty-nine individuals were interested in the study; they were questioned about their diagnosis (or that of the child), level of motor skills and demographical data to assess their eligibility criteria. Out of all the potential participants, eleven participants provided their consent. The low participation rate was attributable to various factors, including ineligibility based on diagnosis, demographic characteristics, or being unresponsive to texts and emails.

Following recruitment, participants were categorized into two groups. The participants had to meet the following criteria to be eligible for the first group: (1) being a parent of a child who experiences difficulties in writing, as identified by a clinician (2) being a parent of a child with a

diagnosis such as CP, DCD and dysgraphia, (3) being a parent of a child with motor impairments, (4) having English or French as their first language and (5) residing in Canada or the United States. The eligibility criteria for the second group were: (1) being an adult who experienced difficulties in writing during their childhood, (2) being an adult with a diagnosis such as CP, DCD or dysgraphia, (3) being an adult with motor impairments (4) having English or French as their first language and (5) residing in Canada or the United States. All participants were provided their informed consent. Including a broad range of participants ensured that diverse perspectives could be obtained to better understand their experiences. Their varied experiences in writing, assistive devices and perspectives on the HAD were beneficial, as the study explored both personal experiences and parental perspectives.

3.2.3. Data collection

The primary method used in our study was semi-structured interviews with participants. Prior to the start of the experiment, nine parents of children with motor impairments (group 1) and two adults with motor impairments (group 2) were sent study information via email and phone calls. They were first shown a brief one-minute video of the HAD's functionalities and mechanism in action. Two scenes were featured in the video: a child and an adult with motor impairments using the HAD to write a word. The video began with a child with sensorimotor deficits tracing the letter 'J' with the pencil holder's sphere grip. Then an adult with CP was seen writing his name 'SEB' smoothly on the pencil holder with a 'L' shaped grip. It should be noted that the two individuals featured in the video had varying degrees of spasticity and used different grasps while writing. The video was replayed twice or thrice to ensure that participants fully understood the

features and functionalities of the HAD. In addition, after watching the video, participants were given the opportunity to ask questions about the HAD.

The interviews, lasting 30 – 60 minutes each, were conducted online (zoom). The interview guide was developed from the HAAT and UTAUT models, consisting of open-ended questions on relevant topics (see appendix B). The five domains of the UTAUT model were used to prepare questions, specifically performance expectancy, effort expectancy, social influence, facilitating conditions and use behaviour (Venkatesh et al., 2003). Using this framework, five different question topics were created: (1) the potential impact of the HAD, (2) its complexity and ease of use, (3) the social influence and anxiety factors associated with the HAD, (4) writing experience across various contexts, and (5) intended behaviour with the HAD.

The Human Activity Assistive Technology (HAAT) was also used to formulate interview questions for both groups in this study to identify the writing difficulties experienced by individuals across different facets of their lives. The HAAT is a dynamic and interactive model which involves four domains: the human, the activity, assistive technology, and the context of the environment. Briefly, it describes “a human doing something in a context using AT” (Cook & Polgar, 2014). The interview questions were guided by the above domains, particularly how the HAD can influence their home, school, and social life to contribute to overall quality of life.

Furthermore, participants were asked to discuss their expectations of the future HAD design concerning the perceived impact on their children (for parents) and reflection on their early childhood (for adults), respectively. These questions align with the assistive domain of the HAAT model. Participants were asked all questions in the interview guide (refer to Appendix B), while

probes and prompts were used whenever necessary. The conducted interviews were audio recorded and transcribed verbatim.

3.2.4. Data analysis

One of the researchers (ASP) listened to the interview recordings and reviewed the transcriptions. The initial coding was done line by line on two interviews using QDA Miner Lite. The codes were then reviewed and clarified with the help of a researcher (PA) and a research assistant. They could agree with, disagree with, or question the codes until a consensus was reached, creating a codebook that was used for the later interviews.

Throughout the process, the transcriptions were continually re-examined and additional codes were created through consensus. The two authors (ASP and PA) and a research assistant then conducted an inductive thematic analysis (Braun & Clarke, 2006) meeting to discuss and agree on the arising themes from the data. The inductive thematic analysis, outlined by Braun and Clarke, worked as follows:

> *"Inductive analysis is a process of coding the data without trying to fit it into a pre-existing coding frame, or the researcher's analytic preconceptions. In this sense, this form of thematic analysis is data-driven" (Braun & Clarke, 2006)*

As the objectives of the study were exploratory, the questions asked during data collection were kept broad and open-ended. At times, the interview guide was put aside to give participants an opportunity to express their personal views, background and social context.

3.3 Results

3.3.1. Demographic profile of participants

A total of eleven participants (9 females and 2 males) consented to participate in the study. The participants included two groups, parents of children with motor impairments (n=9) and adults with motor impairments (n=2), who shared their experiences in writing, the use of assistive devices and their perspectives on the HAD. Tables 2 and 3 illustrate the participants' demographic information.

Table 2.

Demographic profile of parents of children with writing difficulties (group 1; n = 9)

Participants	Sex	Child's age	Child's diagnosis	Residence	School	Experience with AT
P01	Female	16	Dysgraphia	Canada	Regular school	High tech
P02	Female	11	Brain tumor	Canada	Homeschool	High tech
P03	Female	35	Dysgraphia	Canada	Regular school	None
P04	Female	17	DCD and hypotonia	Canada	Homeschool	Low tech
P05	Female	10	DCD, dysgraphia, dyslexia, and dyscalculia	United States	Homeschool	None
P06	Female	8	DCD, ADHD, low muscle tone, speech delay and sensory processing	United States	Regular school	High tech
P07	Female	6	CP	Canada	Homeschool	Low tech
P08	Male	6	CP	Canada	Homeschool	Low tech
P09	Female	10	DCD, dyspraxia and apraxia	Canada	Regular school	High tech

Note: DCD = Developmental Coordination Disorder; CP = Cerebral Palsy; ADHD = Attention Deficit Hyperactive Disorder

Table 3.

Demographic profile of adults with writing difficulties (group 2; n = 2)

Participants	Sex	Child's age	Child's diagnosis	Residence	School	Experience with AT
A01	Male	58	Quadriplegic CP	United States	Regular school	High tech assistive device
A02	Female	26	Mild CP	Canada	Regular school	High tech assistive device

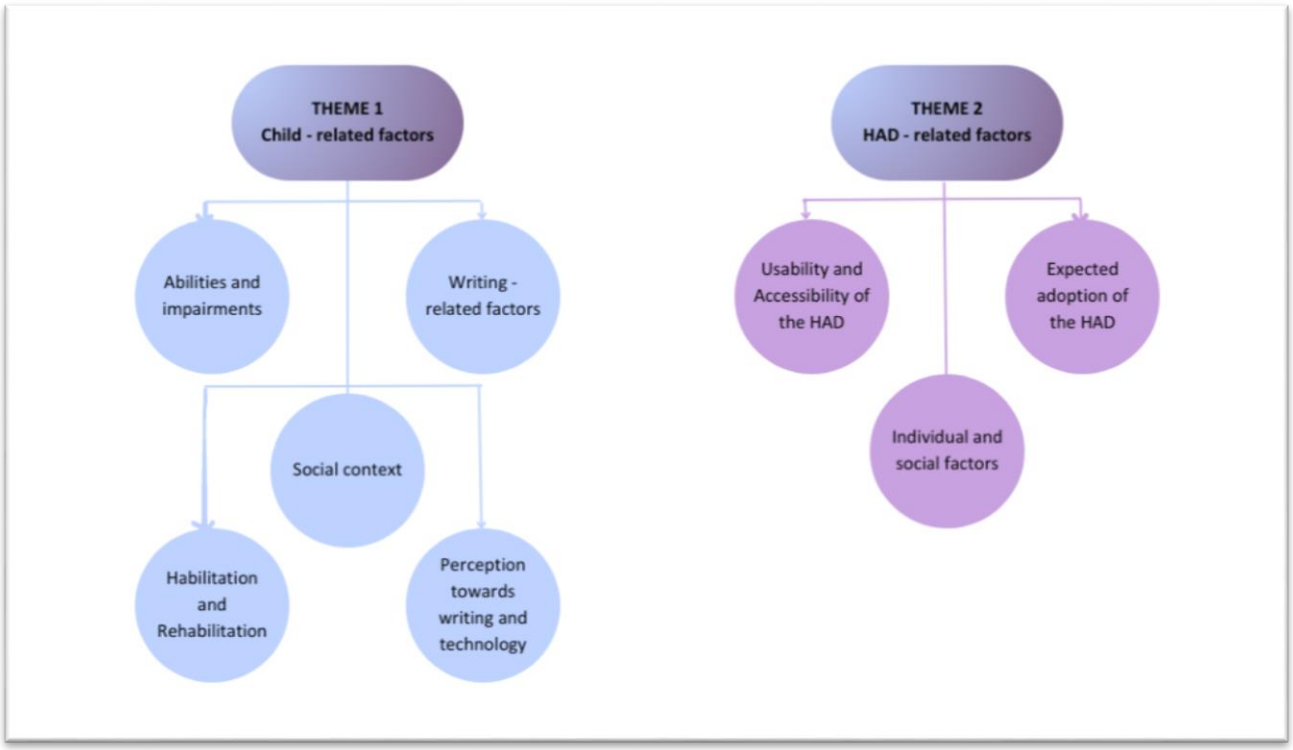
Note: CP = Cerebral Palsy

3.3.2. Qualitative results

The qualitative analysis of the transcripts identified two main themes, namely, (I) Child-related factors with five subthemes and (II) HAD-related factors with three subthemes. The themes and subthemes are illustrated in figure 9. A complete list of themes, subthemes and code definitions can be found in the appendix.

Figure 9

Pictorial representation of the identified themes and subthemes



3.3.2.1. Child-related factors

Child-related factors were a significant theme that emerged in all interviews during the data analysis. This theme ties in with the children's writing experiences and describes their writing difficulties due to their disorders, compensatory strategies, writing experiences influenced by family assistance and barriers in the school, as well as their experiences, struggles and expectations toward assistive technology.

a. Abilities and impairments

Among both groups, impaired or delayed fine motor skill is the prominent symptom affecting the population, irrespective of their age. One of the parents (P01) explained how fine motor skills had affected her child's writing, and she asserted that:

> *[…] He's in the first percentile for fine motor skills, […] he has no idea how even to space himself on a page, he writes all over, he doesn't have any sense of spatial relations on a page, and lines mean nothing, […] they identified him as gifted, he's twice exceptional as they call it […]*

Further, one of the adults (A01) added:

> *[…] makes my life more difficult, in other words, where I was spastic to a certain extent.*

Another parent (P09) highlighted her child's writing experience as painful and discomforting, a common complaint among the pediatric population with writing difficulties.

> *[…] So, at the end of the day, like when we're reading a story at bedtime, and then he's ready to settle…he asks for hand massages […]*

Similarly, she also expressed that writing was a greater cognitive load to her child, which had received far less attention among the participants.

> *[…] he was concentrated on like doing the shape of the letters correctly that he was concentrating so hard.*

As elaborated by other participants, fine motor and cognitive skills were seen as playing an essential role in developing the writing skills of these children, so necessary support must be provided.

b. Writing-related factors

Writing-related factors refer to the components related to writing or the child's feelings/experiences while writing. Each child is unique, and their needs are to be considered when deciding what assistive device is in their best interests. Different factors, such as the child's pencil grasp, drawing skills, writing skills, expressive writing and physical and mental fatigue during the writing, were also brought up during the interview. One of the parents (P02) said:

> *[…] it's just so much effort, so he just will write very, very little, as little as possible […]*

Another adult (A02) explained how writing had affected her academia and negatively impacted her activities of daily living (ADL).

> *[…] I was honestly intimidated by writing at a young age due to not having the same speed as my peers, and this often showed throughout note-taking, essay writing, and homework; I'd feel very rushed and not able to compile my thoughts fast enough.*

c. Social context

Social context refers to the social process of recognizing the individual's abilities to meet their needs with the resources and accommodations available to them. In terms of how participants used clinical interventions such as therapy sessions with OT, school environment and support from family, social context emerged as a major construct. Participants in the present study explored the social context by enhancing interactions with OT or other healthcare professionals, teachers and family through managing their writing difficulties. Parents reported variable experiences with clinical interventions and school, many of which were negative.

> *[…] You know, so even in the best, most supportive environment, which in school is pretty good. It wasn't.* (P01)

[…] I've spent literally hours and hours of my life in school meetings, working with psychologists, working with occupational therapists, working with every professional I could find, technology, people, and we're still doing it.[…] (P01)

In occupational therapy, it got to the point where they said it wasn't actually worthwhile for us to probably do anymore because he's so low on the scale […] (P04)

We kind of had enough. This was hurting him, not helping him. So, we decided to homeschool […] (P05)

Others turned to homeschooling environments to give their children individualized attention to achieve better performance in writing. Even though they worked on these resources regularly, the participants expressed frustration about their child or themselves falling behind in writing.

d. Habilitation and rehabilitation

The participants reported that handwriting intervention programs and assistive technology were the primary ways they received support for their children or their own writing. By far, the most common AT used among children are larger pencils, pencil grip adaptations, as well as digital solutions such as mobile applications, laptops and tablets. The primary use of digital AT was for dictation and typing.

Given the above, it is not surprising that one of the most common responses to what would have helped the children's writing, the parents found the AT as "too overwhelming," "complicated," and requiring "extra steps." Further, some participants had a positive experience with speech recognition apps for dictation, even though their use was associated with a steep learning curve. One of the participants reported that they lacked interfaces that worked smoothly with Google voice-to-text, posing additional challenges to a robust solution. Even those participants who were

more tolerant of the resources expressed their disappointment over the time it took for their children's writing experience. For example, one parent (P01) stated:

> *[…] We still haven't found one that really suits our needs.*

e. Perception towards writing and technology

The relationship of participants among affective, cognitive and behavioural components of the attitude construct between writing and technology was explored. It was clear from the interviews that participants took on or felt compelled to take on the AT, which they saw as providing a facilitating role for their children's writing. One of the parents (P01) captured this in the interview:

> *He was not really showing any improvement; we just […] shifted our focus to […] using technology.*

AT was sometimes described as having more influence over writing and as *"…that would make these people more independent."* On the one hand, participants felt too much effort and time was required for children to write letters, so they found AT could constitute an engaging and independent solution. On the other hand, some parents(P06) felt that their child might resist change, *"he finally embraced the technology once […] he realized he didn't have a choice"*. They emphasized that they had difficulty during the children's transition to AT. Overall, based on the parent's experiences with their children, using AT to support writing also had its own challenges, such as losing interest in AT over time, lack of extrinsic motivation, an uncertain timeline for the AT learning curve and preference over digital AT.

3.3.2.2. HAD-related factors

HAD-related factors were a significant theme that emerged in all interview transcripts during the data analysis. This theme discusses the design features of the HAD, the potential use of the HAD in personal, social contexts and how it might support their early childhood development and writing. Specifically, participants identified factors that are significant in the HAD, as well as their perceived needs for a writing assistive device.

a. Acceptability and accessibility of the HAD

This subtheme describes the ease of use and flexibility level identified by the participant's perception of the HAD. In addition, this also includes the individual components of the HAD, such as size, rotatory arm, pencil handle and dampers, while interacting with it.

Participants felt that the design of the HAD was "neat," "simple," "interesting," and "straightforward." This point was particularly relevant, as writing aids should help children write easily. Interestingly, a few participants also shared the same belief, stating that "it would not be overwhelming as a writing tool." Further, most of the participants expressed their interest in the adaptive pencil handles of the HAD, which can be interchanged into different shapes according to the children's grip development.

> *[…] it was cushioned in the right places so that it's comfortable to hold.* (P07)

Others were attracted to the idea of 3D-printed pencil handles, which would help minimize the HAD cost while improving accessibility and affordable childcare. Furthermore, a few of the participants pointed out that the HAD's dampers would be helpful for their child's hypotonia to

address the concerns with proper grip and hand strength. It was asserted by one of the parents (P02):

> *I liked the idea that it would break involuntary movements because I could see how that would really help […] that would be a big improvement.*

b. Expected adoption of the HAD

This subtheme highlights the impact parents and adults felt the HAD could have on the children's writing and their writing, respectively. The subtheme also describes the participant's willingness to adopt the HAD, introducing it as an intervention in their child's formal years of instruction and strategies to use it effectively.

When factoring in the participant's positive perspectives on the HAD, almost all were impressed with the HAD's mechanism and found it a "super helpful" device for writing. A key insight from their perspectives was that the HAD could facilitate children's independence, decrease the time involved in writing, allows them to participate as much as typically developed children, promotes effective classroom participation, and has the potential to improve the children's grip. A primary factor in the parent's perspective of the HAD was its ability to prompt their children in writing while mechanically supporting their movements. Many of the participants were impressed with its design and mechanism:

> *[…] sounds like they turned a fine motor skill into a gross motor skill.* (P01)

> *[…] It is almost like a hand-over-hand system […]* (P09)

While the participants appreciated the design of the HAD, they also raised questions about its portability, size and how accommodating it would be to write small letters with the HAD.

Participants also gained a new perspective on how the HAD could be used as an intervention during the formal years of instruction. For example, they mentioned that children could begin to write with the HAD starting at the age of five. Similarly, another parent (P04) indicated that the HAD could potentially "act as a progressive tool for writing" in handwriting interventions. This suggests that it could be used as a traditional model adapted to facilitate and support the grasp development and writing throughout childhood.

Furthermore, parents shared strategies to implement the HAD in everyday life by making it more personalized to their children's needs. One parent (P06) said she would allow her child to compete with himself by timing his writing tasks; another (P05) added that she would progressively assign tasks to her child. These discussions helped to understand that the strategies differed with children's challenges. However, it is evident that the HAD can act as a critical tool in addressing their demands in writing.

c. Individual and social factors

This subtheme explores the relationship of individual and social factors in using the HAD in children's writing. It encompasses the participant's attitude toward the perceived performance expectancy of the HAD, their perceived stigma and strategies to tackle the social challenges.

Firstly, the participants reported positive perspectives related to the potential performance of the HAD; they expressed a sense of confidence, stability and autonomy to tackle their children's writing experience. However, some participants addressed concerns based on individual

preferences or social factors. In the case of personal concerns, participants evoked the possibility of annoyance and frustration due to their children's emotional and physical fatigue during a writing intervention. Further, one of the parents (P02) described that his child would prefer a digital writing device, saying

> *[…] tinkering with something that's in metal […] I don't know to what extent he would have found that fun.*

At the same time, another parent (P09) argued that her child would be curious about the HAD as her son is drawn to mechanical objects and tools.

Secondly, solicitude was expressed by parents whose children had a hard time dealing with assistive devices. Younger children compare their differences and special needs with their friends and siblings, making it difficult for them to adapt to any assistive device. Considering this, participants were concerned about their children's emotional and social states if they were to use the HAD. These comments are telling:

> *[…] anything that says I'm special […] is a no for him.* (P02)
>
> *[…] visual difference from what everyone is using, and as a 10-year-old boy, I think it would be different in a mainstream classroom.* (P09)

However, even participants who argued that the HAD would not be an ideal solution for their children believed their children might grow on it. They also commented that it would no longer be a struggle if their children got past their teenage years.

> *I think once you get to like college and university, I think […] people just kind of acknowledge that, OK, yeah, it's a tool* (P09)

It was also asserted by a participant in her late 20s (A02) who struggled with writing difficulties due to CP and appreciated the inclusion and accessibility that the HAD could offer.

> *I wouldn't have ashamed of having a disability, instead would've encouraged to participate […] world back then wasn't as accepting of difficulties as it is today.*

Finally, the participants also figured out how to integrate the HAD while navigating the social contexts and dealing with their traits. They suggested it could be designed in a more compact size with vibrant colours, making it more personalized, fun and refreshing. They also said it should be integrated into their formative years before they have social experiences to compare their differences with other children. Further, they also commented on the potential role of teachers in making the HAD engaging and approachable in a classroom setting and on how classmates may perceive it.

3.4 Discussion

The goal of our study was achieved, as it provided insights into the perspectives of both parents and adults on the potential use of the HAD for children and individuals with writing difficulties due to motor impairments, from neurological conditions such as DCD, CP and dysgraphia. We were able to document the participant's perspectives on the HAD's social context, acceptability and accessibility. Nearly all participants reported a positive impression of the HAD's design and its potential to improve their writing skills.

3.4.1. A desire for a change

This research study examined the potential use of the HAD in promoting traditional writing among children with writing difficulties. It provided insights into the perceptions and experiences regarding the use of AT for writing, including their preferences and expectations. Our findings align with prior research on the need for assistive devices for children with motor impairments (Denton et al., 2006; Osugi et al., 2019). Specifically, the findings indicate that the participants considered digital AT as a last resort only when handwriting interventions and low-tech assistive devices do not seem effective for the children. They also reported that the digital AT helped them complete school assignments on time while compensating for their writing difficulties. Additionally, some participants recognized the significance of traditional writing and understood how the HAD could support their children's development, resulting in their eagerness to adopt it into their children's lives. Although parents understood the importance of traditional writing (Longcamp et al., 2005; Mayer et al., 2020), they had contrasting views on adopting the HAD into their child's life. Specifically, some preferred digital AT over the HAD because it would allow their children to blend into their social environment more easily.

Another important finding is that the participants preferred an assistive device that supports their child's or their own needs while not exhausting them physically or mentally. Notably, the HAD was perceived to have the potential to be helpful for individuals with spasticity and grasp development. The HAD's simple design, soft learning curve, portability and interactivity potentially contributed to a positive opinion among the participants. However, the study also identified some limitations in the participant's perceptions of the HAD due to the lack of actual interaction with the device, making it challenging for them to attain the required trust. Reliability

and trust are indeed essential aspects while dealing with an assistive device (Schwaninger, Güldenpfennig, Weiss, & Fitzpatrick, 2021).

Further, participants also suggested that a smaller size and more vibrant colours could make the HAD more accessible among the pediatric population. Overall, the study sheds light on the perceptions and expectations of the participants regarding HAD, which is crucial in the development of assistive technology. While the HAD showed promise as a potential assistive device, further research is needed to evaluate its effectiveness and usability in real-world settings.

3.4.2. Influence of identity

The study's results demonstrated that the potential use of the HAD for children with writing difficulties may have had both positive and negative effects on their children's abilities and well-being. On the one hand, parents reported that the HAD could instill confidence in their children's own abilities and improve autonomy in their writing experience. This is an important finding as confidence and autonomy are essential factors in the development of children (Pape, Kim, & Weiner, 2002; Phillips & Zhao, 1993). In turn, it can positively affect their acceptance of the HAD, motivating them to integrate it into their daily routine. This must be noted as motivation acts as a primary construct in the acceptance of technology (Pape, Kim, & Weiner, 2002; Phillips & Zhao, 1993). On the other hand, other parents in our study also explained that the HAD could be intimidating for some parents and children. In particular, children with disabilities may have a less positive self-identity than typically developed children (Hammar, Ozolins, Idvall, & Rudebeck, 2009), and the use of HAD may exacerbate these negative feelings. The participants further

added that maybe the use of the HAD could be accompanied by stigma and feelings of frustration, leading to lowered self-esteem, which would ultimately threaten the children's identity and not necessarily improve their writing experience (Longcamp et al., 2005). Thus, the study's results highlighted that the use of the HAD could potentially reduce a child's writing difficulties and enhance independence and autonomy; but depending on context it could instead threaten a child's identify or self-image.

3.4.3. Adoption of the HAD

The examination of the intersection of the participants' home, school and social contexts provided a glimpse of their writing difficulties and experiences with existing AT. Their perspectives highlighted that adopting the HAD may potentially help children strengthen their grasp, improve their writing performance, encourage their involvement in school activities and help them become more independent. More specifically, participants in our study revealed that the HAD has the potential to promote writing during the early years of formal instruction. The results are consistent with user perspective theory, highlighting that users are more likely to adopt and use assistive devices if it improves their performance and effectively address their needs (Kintsch & Depaula, 2002).

However, previous research has highlighted that with any assistive device, acceptance is crucial in understanding how users perceive the device and effectively use it for their needs (Venkatesh et al., 2003). The participants of the study stressed the importance of understanding the acceptance of the HAD among the pediatric population. Indeed, some parents indicated they would have been reluctant to adopt it into their children's lives despite recognizing its potential

benefits. The main reasons provided were their children's resistant to change and the perceived risk of social stigma associated with the HAD. To address these concerns and promote the acceptance of the HAD, it is essential to consider the children's and their parent's perspectives throughout the future development of the HAD and to engage them in the decision-making process of the design and selection of the AT. Previous research has indeed shown that involving children in selecting their assistive devices increases acceptance as it helps them to shape their individualized meanings towards the device (Pape et al., 2002). In addition, parents can play a collective role in influencing their children's identity towards assistive devices ("Government of Alberta," 2020; Ulferts, 2020). As the current study already explored the parent's perspective towards the HAD, future studies could focus on the children's perspective towards the HAD and consider their opinions for the continued HAD's development.

3.5 Limitations

The study has its own limitations. Due to the COVID-19 pandemic, remote interviews were used to collect the data, limiting the participant's interaction with the HAD. They did not have the opportunity to interact directly with the HAD, and their perspectives were limited to their understanding of its features, observed in possibly different contexts. This lack of direct interaction with the HAD may have limited the validity of the study's findings. The study's rigor and trustworthiness could have been improved by implementing member checking, where the researcher (ASP) sends a summary of the interview to the participants after the remote interviews to confirm the accuracy of the interpretation. On the other hand, the trustworthiness of the study was enhanced by having three researchers collaborate on the initial coding stages and develop a codebook. Another limitation is that the study had a higher participation rate from

female parents who responded to the invitation to participate. Thus, the findings might not be exhaustive due to the gender imbalance, as male and female parents may perceive their child's writing difficulties and the potential use of the HAD differently.

3.6 Conclusion

The findings revealed that the HAD could positively impact the child's grasp, spasticity and writing performance. At the same time, it also illustrated that the HAD could positively and negatively affect children's identities. Furthermore, it is important to listen to the opinions of parents about a new assistive device in relation to its design, performance and participation. Therefore, it implies that these study's results intend to help pediatric therapists in acknowledging the parent's perspectives when introducing the HAD and how it would fit into the children's and families' daily lives. Finally, the results from this study support the use of the HAD as an intervention and contribute to the further development of the device in an effort to develop long-lasting effects on children's writing skills. Overall, the study's findings may inform the engineers on how to improve the overall design of the HAD. It may also inform the rehabilitation research communities to introduce relevant strategies among children with writing difficulties. Still, more research would be needed to fully assess the HAD's effectiveness in meeting their needs and demands in real-world settings.

4 CHAPTER 4: General discussion and conclusion

In this study, the perspectives of parents of children with motor impairments and of adults with motor impairments were explored to broaden the understanding of both the groups related to the impact the HAD might have on a pediatric population with writing difficulties.

4.1 Summary of findings

Considering the emphasis on the children's profile, the information that has been collected from the parents about their children, as well as adults on their childhood, is relevant to filling the gaps in AT research, especially in relation to writing difficulties (Rocha & De Jesus, 2022; Rosenbaum et al., 2007; Schwellnus et al., 2012), experience with AT (Svensson et al., 2021) and minimizing the spasticity or involuntary movements (Osugi et al., 2019). Interestingly, participants indicated a positive impression of the HAD regarding its design, ease of use, accessibility, and user acceptability. This fact leads us to infer that the HAD could potentially improve children's writing goals and performance. According to the results, some parents considered that writing with the HAD might effectively reduce the effects of spasticity and provide support while they write. Further, the adults participants added that using the HAD would have allowed for effective classroom participation in their childhood. The above points out that the HAD could positively affect muscle tone, grasp, and involuntary movements – while establishing autonomy earlier in a child's life by providing more opportunities in other aspects of their development.

Another important point highlighted in this study is how the HAD could be used as a progressive intervention in children's formal years of instruction, by integrating it at home or school, depending on their learning environments. This is in line with our findings, which revealed that

using the HAD's pencil grasp might support the children's various stages of grasp development and offer a stable condition regarding spasticity.

Furthermore, the results showed that some parents perceived the HAD as unfavorable. They expressed their worry that the HAD might bring more attention to the child and enhance their perception of being different. Despite that, the results also indicated that some of the parents were willing to adopt the HAD in their children's lives – stating that the social focus on HAD doesn't necessarily have to be negative if the HAD had a rewarding and positive effect on their child.

4.2 Significance and future directions

This study demonstrated that the HAD might positively influence children with writing difficulties in terms of writing performance, user acceptability, and accessibility. The present study's exploration has allowed a deeper understanding of how an assistive device such as the HAD may fit with the children and their family's lives, with respect to writing and participation. It may enable them to manage their own care and development while providing them with autonomy and helping set individualized goals toward writing performance.

Another dimension we examined in the study is whether the HAD could act as an intervention in children's formal years of instruction. It is well evident from the results that the parental group is willing to adopt the HAD in their children's lives throughout the early stages of writing and grasp development. Although it has been pointed out by the parents that they might not prefer the HAD for children who are transitioning to their teenage years. This is because the HAD is larger, which would limit the optimal size of letters, words or texts while writing. Therefore,

advances in the design and size of the HAD can be carried out in the future to provide a unifying tool for children above the age of fifteen and to reflect a broader perspective. Also, it is important to point out that the study did not validate the effectiveness of the HAD among children with writing difficulties. So, future research should focus on the impact of the HAD's participation, usability and performance for children with motor impairments and how effective it would be in the long term.

The present study illustrated the experiences of parents in terms of writing, the challenges and AT they encountered and the perceived impact of the HAD in different contexts of everyday life. The sample included a diverse array of experiences, encompassing various impairments and disorders and the age of the individual and the parent. They presented different writing needs, expectations and detailed perspectives on the HAD, strategies to improve the writing with the HAD and suggestions for further design. For HAD design, individuals with writing difficulties and parents should have a greater role in its continued development. Thus, the results obtained in the study can be used for future research and further design and development of the HAD.

Moreover, this thesis provides a deeper understanding of the HAD for rehabilitation professionals, which is essential when introducing a new assistive device or writing intervention in a child's life. It helps them to acknowledge both the individual's and parent's experience while developing their rehabilitation plans and how they might fit in their families' lives. The present results could also help them to strategize their plans for development activities related to writing performance, spasticity and fine motor skills for children with writing difficulties. Overall, the findings reveal that HAD has the potential to improve the writing performance of children with writing difficulties, from small changes to improvements that make a difference in their everyday

lives. It also provides valuable insight into optimal ways to adopt the HAD as a writing intervention, thus boosting the writing experiences among the pediatric population with writing difficulties.

5 CHAPTER 5: References

Alaniz, M. L., Galit, E., Necesito, C. I., & Rosario, E. R. (2015). Hand Strength, Handwriting, and Functional Skills in Children With Autism. Am J Occup Ther, 69(4), 6904220030p1–6904220030p9. doi:10.5014/ajot.2015.016022

Alaniz, M. L., Galit, E., Necesito, C. I., & Rosario, E. R. (2015). Hand Strength, Handwriting, and Functional Skills in Children With Autism. *Am J Occup Ther, 69*(4), 6904220030p6904220031-6904220039. doi:10.5014/ajot.2015.016022

Alomary, A., & Woollard, J. (2015). *How is technology accepted by users? A review of technology acceptance models and theories*.

Amundson, S. J. (1995). Evaluation Tool of Children's Handwriting: ETCH examiner's manual. *Homer, AK: O.T. Kids.*

Assistive Technology Act, § 1401 (2004).

Batshaw, M. L. (2007). *Children with disabilities* (6 ed.).

Bax, M., Goldstein, M., Rosenbaum, P.,. (2005). Proposed definition and classification of cerebral palsy. *Developmental Medicine and Child Neurology, 47*, 571 - 576.

Beery, K. E. (1997). The Beery-Buktenica developmental test of visual motor integration with supplemental developmental tests of visual perception and motor coordination. . *New Jersey: Modern Curriculum Press.*

Beery, K. E., Buktenica, N. A., & Beery, N. A. (2010). The Beery Developmental Test of Visual-Motor Integration (6th ed). *Journal of Psychoeducational Assessment, 30*(6), 588 - 592.

Berninger, V. W., Abbott, R. D., Jones, J., Wolf, B. J., Gould, L., Anderson-Youngstrom, M., . . . Apel, K. (2006). Early development of language by hand: composing, reading, listening, and speaking connections; three letter-writing modes; and fast mapping in spelling. *Dev Neuropsychol, 29*(1), 61-92. doi:10.1207/s15326942dn2901_5

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. doi:10.1191/1478088706qp063oa

Cahill, S. (2009). Where Does Handwriting Fit In?Strategies to Support Academic Achievement. *Intervention in School and Clinic - INTERVENTION SCHOOL CLINIC, 44*, 223-228. doi:10.1177/1053451208328826

Case-Smith, J., & O'Brien, J. C. (2015). *Occupational therapy for children and adolescents* (Seventh ed.).

Cole, J., & Swinth, Y. (2004). Comparison of the TouchFree Switch to a Physical Switch; Children's Abilities and Preferences: A Pilot Study. *Journal of Special Education Technology, 19*(2), 19-30. doi:10.1177/016264340401900202

Cook, A. M., & Polgar, J. M. (2014). *Assistive technologies: Principles and practice: Fourth edition*.

Daly, C. J., Kelley, G. T., & Krauss, A. (2003). Relationship between visual-motor integration and handwriting skills of children in kindergarten: a modified replication study. *Am J Occup Ther, 57*(4), 459-462. doi:10.5014/ajot.57.4.459

Denton, C. A., Fletcher, J. M., Anthony, J. L., & Francis, D. J. (2006). An evaluation of intensive intervention for students with persistent reading difficulties. *J Learn Disabil, 39*(5), 447-466. doi:10.1177/00222194060390050601

Erhardt, R. P. (1994). Using the Erhardt Developmental Prehension Assessment. *The Occupational Therapy Journal of Research, 14*(3), 143 - 211. doi:https://doi.org/10.1177/153944929401400301

Exner, C. E. (2006). *Chapter 12 – Intervention for Children with Hand Skill Problems*.

Feder, K. P., & Majnemer, A. (2007). Handwriting development, competency, and intervention. *Dev Med Child Neurol, 49*(4), 312-317. doi:10.1111/j.1469-8749.2007.00312.x

Freeman, A. R., Mackinnon, J. R., & Miller, L. T. (2005). Keyboarding for students with handwriting problems: a literature review. *Phys Occup Ther Pediatr, 25*(1-2), 119-147. doi:10.1080/J006v25n01_08

Ghasia, F., Brunstrom, J., Gordon, M., & Tychsen, L. (2008). Frequency and severity of visual sensory and motor deficits in children with cerebral palsy: gross motor function classification scale. *Invest Ophthalmol Vis Sci, 49*(2), 572-580. doi:10.1167/iovs.07-0525

Goldstand, S., Bissell, J., & Cermak, S. A. (2013). *Here's how I Write: A Child's Self-assessment and Goal Setting Tool: Improving Handwriting Abilities in School-aged Children*: Therapro, Incorporated.

Gordon, A. M., Charles, J., & Steenbergen, B. (2006). Fingertip Force Planning During Grasp Is Disrupted by Impaired Sensorimotor Integration in Children With Hemiplegic Cerebral Palsy. *Pediatric Research, 60*(5), 587-591. doi:10.1203/01.pdr.0000242370.41469.74

Government of Alberta, (2020).

Grotto Grip. Retrieved from https://pathwaysforlearning.com/grotto-grip/

Haberfehlner, H., Visser, B., Daffertshofer, A., van Rossum, M. A., Roorda, L. D., van der Leeden, M., . . . Hoeksma, A. F. (2011). Handwriting difficulties in juvenile idiopathic arthritis: a pilot study. *Clin Exp Rheumatol, 29*(5), 887-893.

Himmelmann, K., Hagberg, G., Wiklund, L. M., Eek, M. N., & Uvebrant, P. (2007). Dyskinetic cerebral palsy: a population-based study of children born between 1991 and 1998. *Developmental Medicine & Child Neurology, 49*(4), 246 - 251.

Idor Svensson, T. N., Emma Lindeblad, Stefan Gustafson, Marianne Björn, Christina Sand, Gunilla Almgren/Bäck & Staffan Nilsson (2021). Effects of assistive technology for students with reading and writing disabilities. *Disability and Rehabilitation: Assistive Technology, 16*(2), 196 - 208. doi:10.1080/17483107.2019.1646821

The International Organization for Standardization, (1999).

James, K. H., & Engelhardt, L. (2012). The effects of handwriting experience on functional brain development in pre-literate children. *Trends Neurosci Educ, 1*(1), 32-42. doi:10.1016/j.tine.2012.08.001

Jane Case-Smith, J. C. O. B. (2014). *Occupational Therapy for Children and Adolescents - E-Book*.

John, S., & Renumol, V. G. (2018). *Impact of Fine Motor Skill Development App on Handwriting Performance in Children with Dysgraphia: A Pilot Study*.

Kadar, M., Wan Yunus, F., Tan, E., Chai, S. C., Razaob Razab, N. A., & Mohamat Kasim, D. H. (2020). A systematic review of occupational therapy intervention for handwriting skills in 4-6 year old children. *Aust Occup Ther J, 67*(1), 3-12. doi:10.1111/1440-1630.12626

Kaminski, J. W., Valle, L. A., Filene, J. H., & Boyle, C. L. (2008). A meta-analytic review of components associated with parent training program effectiveness. *J Abnorm Child Psychol, 36*(4), 567-589. doi:10.1007/s10802-007-9201-9

Karlsdottir, R., & Stefansson, T. (2002). Problems in developing functional handwriting. *Percept Mot Skills, 94*(2), 623-662. doi:10.2466/pms.2002.94.2.623

Kim, B., In, H., Lee, D.-Y., & Cho, K.-J. (2017). Development and assessment of a hand assist device: GRIPIT. *Journal of NeuroEngineering and Rehabilitation, 14*(1), 15. doi:10.1186/s12984-017-0223-4

Kintsch, A., & Depaula, R. (2002). A framework for the adoption of assistive technology. *Proceedings of SWAAAC 2002: Supporting Learning Through Assistive Technology*.

Koziatek, S. M., & Powell, N. J. (2003). Pencil grips, legibility, and speed of fourth-graders' writing in cursive. *Am J Occup Ther, 57*(3), 284-288. doi:10.5014/ajot.57.3.284

Lemire, G., Laliberté, T., Turcot, K., Flamand, V., & Campeau-Lecours, A. (2019). *Preliminary design of a device to assist handwriting in children with movement disorders*.

Link, L. K., Lukens, S. A., & Bush, M. A. (1995). Spherical grip strength in children 3 to 6 years of age. *The American journal of occupational therapy : official publication of the American Occupational Therapy Association, 49 4*, 318-326.

Longcamp, M., Zerbato-Poudou, M.-T., & Velay, j.-l. (2005). The Influence of Writing Practice on Letter Recognition in Preschool Children: A Comparison between Handwriting and Typing. *Acta psychologica, 119*, 67-79. doi:10.1016/j.actpsy.2004.10.019

Mathiowetz, V., Wiemer, D. M., & Federman, S. M. (1986). Grip and pinch strength: norms for 6- to 19-year-olds. *Am J Occup Ther, 40*(10), 705-711. doi:10.5014/ajot.40.10.705

Mayer, C., Wallner, S., Budde-Spengler, N., Braunert, S., Arndt, P. A., & Kiefer, M. (2020). Literacy Training of Kindergarten Children With Pencil, Keyboard or Tablet Stylus: The Influence of the Writing Tool on Reading and Writing Performance at the Letter and Word Level. *Frontiers in Psychology, 10*. doi:10.3389/fpsyg.2019.03054

McKenzie, K., Miller, C., Mosley, S., & Saathoff, J. (2008). United States Patent No.

Medwell, J., Strand, S., & Wray, D. (2009). The links between handwriting and composing for Y6 children. *Cambridge Journal of Education, 39*, 329-344. doi:10.1080/03057640903103728

Missiuna, C., Mandich, A. D., Polatajko, H. J., & Malloy-Miller, T. (2001). Cognitive orientation to daily occupational performance (CO-OP): part I--theoretical foundations. *Phys Occup Ther Pediatr, 20*(2-3), 69-81. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/11345513

Novak, I., Hines, M., Goldsmith, S., & Barclay, R. (2012). Clinical prognostic messages from a systematic review on cerebral palsy. *Pediatrics, 130*(5), e1285-1312. doi:10.1542/peds.2012-0924

Ohgi, S., Takahashi, T., Nugent, J., Arisawa, K., & Akiyama, T. (2003). Neonatal Behavioral Characteristics and Later Behavioral Problems. *Clinical pediatrics, 42*, 679-686. doi:10.1177/000992280304200803

Ose Askvik, E., van der Weel, F. R. R., & van der Meer, A. L. H. (2020). The Importance of Cursive Handwriting Over Typewriting for Learning in the Classroom: A High-Density EEG Study of 12-Year-Old Children and Young Adults. *Front Psychol, 11*, 1810. doi:10.3389/fpsyg.2020.01810

Oskoui, M., Coutinho, F., Dykeman, J., Jette, N., & Pringsheim, T. (2013). An update on the prevalence of cerebral palsy: A systematic review and meta-analysis. *Developmental Medicine and Child Neurology, 55*. doi:10.1111/dmcn.12080

Osugi, K., Ihara, A. S., Nakajima, K., Kake, A., Ishimaru, K., Yokota, Y., & Naruse, Y. (2019). Differences in Brain Activity After Learning With the Use of a Digital Pen vs. an Ink Pen-An Electroencephalography Study. *Front Hum Neurosci, 13*(275), 275. doi:10.3389/fnhum.2019.00275

Pape, T. L.-B., Kim, J., & Weiner, B. (2002). The shaping of individual meanings assigned to assistive technology: a review of personal factors. *Disability and Rehabilitation, 24*(1-3), 5-20. doi:10.1080/09638280110066235

Parette, H. P., & VanBiervliet, A. (1990). A Prospective Inquiry into Technology Needs and Practices of School-Age Children with Disabilities. *Journal of Special Education Technology, 10*(4), 198-206. doi:10.1177/016264349001000403

Phillips, B., & Zhao, H. (1993). Predictors of assistive technology abandonment. *Assist Technol, 5*(1), 36-45. doi:10.1080/10400435.1993.10132205

Rocha, C. F., & De Jesus, O. (2022). *Dysgraphia.*: Treasure Island (FL): StatPearls Publishing.

Rosenbaum, P., Paneth, N., Leviton, A., Goldstein, M., Bax, M., Damiano, D., . . . Jacobsson, B. (2007). A report: the definition and classification of cerebral palsy April 2006. *Dev Med Child Neurol Suppl, 109*, 8-14.

Schwellnus, H., Carnahan, H., Kushki, A., Polatajko, H., Missiuna, C., & Chau, T. (2012). Effect of pencil grasp on the speed and legibility of handwriting after a 10-minute copy task in Grade 4 children. *Aust Occup Ther J, 59*(3), 180-187. doi:10.1111/j.1440-1630.2012.01014.x

Shumway-Cook, A. W., M. (2001). *Motor control theory and practical applications* (2 ed.).

Stiles, J., Sabbadini, L., Capirci, O., & Volterra, V. (2000). Drawing Abilities in Williams Syndrome: A Case Study. *Developmental Neuropsychology, 18*(2), 213-235. doi:10.1207/S15326942DN1802_4

Stott, D. H., Henderson, S. E., & Moyes, F. A. (1987). Diagnosis and Remediation of Handwriting Problems. *Adapted Physical Activity Quarterly, 4*(2), 137-147. doi:10.1123/apaq.4.2.137

Svensson, I., Nordström, T., Lindeblad, E., Gustafson, S., Björn, M., Sand, C., . . . Nilsson, S. (2021). Effects of assistive technology for students with reading and writing disabilities. *Disabil Rehabil Assist Technol, 16*(2), 196-208. doi:10.1080/17483107.2019.1646821

Swinth, Y., & Case-Smith, J. (1998). Assistive technology in early intervention: Theory and practice. *Pediatric occupational therapy and early intervention*, 277-298.

Taras, H., Brennan, J., Gilbert, A., & Eck Reed, H. (2011). Effectiveness of Occupational Therapy Strategies for Teaching Handwriting Skills to Kindergarten Children. *Journal of Occupational Therapy, Schools, & Early Intervention, 4*(3-4), 236-246. doi:10.1080/19411243.2011.629554

Ulferts, H. (2020). Why parenting matters for children in the 21st century. doi:doi:https://doi.org/10.1787/129a1a59-en

UNICEF, WHO, (2018).

Venkatesh, Morris, Davis, & Davis. (2003). User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly, 27*(3), 425-478. doi:10.2307/30036540

Wanja, T. (2021). Thixotropic Pen: Fat Ergonomic Pens for Arthritic and Parkinson's Hands. Retrieved from https://hosiped.com/fat-pens-for-arthritic-hands/

Weintraub N, G. S. (1998). Writing legibly and quickly: A study of children's ability to adjust their handwriting to meet common classroom demands. *Learning Disabilities Research & Practice, 13*(3), 146 - 152.

Wu, F.-G., Chang Eva, Chen Rain, Chen Chien-Hsu. (2003). Assistive drawing device design for Cerebral Palsy children. *Technology and Disability, 15*(4), 239 - 246.

Ziviani, J., & Wallen, M. (2006). Chapter 11 - The Development of Graphomotor Skills. In A. Henderson & C. Pehoski (Eds.), *Hand Function in the Child (Second Edition)* (pp. 217-236). Saint Louis: Mosby.

Ulferts, H. (2020). Why parenting matters for children in the 21st century. doi:doi:https://doi.org/10.1787/129a1a59-en

UNICEF, WHO, (2018).

Venkatesh, Morris, Davis, & Davis. (2003). User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly, 27*(3), 425-478. doi:10.2307/30036540

Wanja, T. (2021). Thixotropic Pen: Fat Ergonomic Pens for Arthritic and Parkinson's Hands. Retrieved from https://hosiped.com/fat-pens-for-arthritic-hands/

Weintraub N, G. S. (1998). Writing legibly and quickly: A study of children's ability to adjust their handwriting to meet common classroom demands. *Learning Disabilities Research & Practice, 13*(3), 146 - 152.

Williams, H. (2002). Motor control in children with Developmental Coordination Disorder. *Developmental Coordination Disorder*, 117-137.

Wu, F.-G., Chang Eva, Chen Rain, Chen Chien-Hsu. (2003). Assistive drawing device design for Cerebral Palsy children. *Technology and Disability, 15*(4), 239 - 246.

Ziviani, J. (1983). Qualitative changes in dynamic tripod grip between seven and 14 years of age. *Dev Med Child Neurol, 25*(6), 778-782. doi:10.1111/j.1469-8749.1983.tb13846.x

Ziviani, J., & Wallen, M. (2006). Chapter 11 - The Development of Graphomotor Skills. In A. Henderson & C. Pehoski (Eds.), *Hand Function in the Child (Second Edition)* (pp. 217-236). Saint Louis: Mosby.

Zwicker, J. G., & Hadwin, A. F. (2009). Cognitive versus Multisensory Approaches to Handwriting Intervention: A Randomized Controlled Trial. *OTJR: Occupation, Participation and Health, 29*(1), 40-48. doi:10.1177/153944920902900106

6 CHAPTER 6: Appendices

Appendix A

Consent form

INFORMED CONSENT TO PARTICIPATE IN A STUDY ENTITLED

Usability of an assistive device for writing in children with writing difficulties

Principal investigators:

Antony Shruti, MSc student, McGill University
Philippe Archambault, OT, PhD, McGill University
Véronique Flamand, OT, PhD, Laval University
Dana Anaby, OT, PhD, McGill University

This project aims to determine whether a writing assistive device improves drawing and writing performance among children with writing difficulties due to physical or neurological disabilities. Before agreeing to participate in this project, kindly allow the time to go through the information carefully.

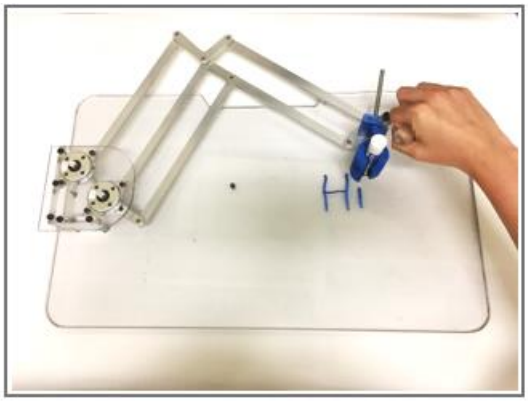
This consent form states the objective of the study, procedure, benefits, potential risks, and the person to contact in case of emergency. This consent form may have a vocabulary that you might not understand. You are welcome to approach the researcher and the other members of the research project.

Description and Objective of the Research Study

Writing is an essential skill for self-expression and communication in childhood. As such, writing skill often takes time to develop in children. However, some children suffer from movement

disorders that can make it difficult for children to use or grip the pencil effectively. To mitigate their writing difficulties, a Handwriting Assistive Device has been designed to assist the children in writing. It consists of an articulated arm, an adjustable pencil handle and a writing base. It can be used with pencils or crayons of different sizes. It assists in drawing and writing tasks by providing support and reducing uncoordinated movements. In addition, we will also explore the thoughts of parents about the use of the HAD. This knowledge will help us create a stimulating environment for the children at home and school, while also developing a future design for their needs.

Nature of Participation



This research will involve your participation in a one-on-one session that will take about fifteen to twenty minutes. The interview will take place virtually through Teams or Zoom. If you do not wish to answer any of the questions during the interview, you may say so, and the interviewer will move on to the next question. No one else but the interviewer will be present virtually unless you would like someone else to be there. The entire session will be recorded, but no one will be identified by name. The recorded information will be kept confidential.

Benefits from your participation

This study does not guarantee any direct benefit. However, the research study will help us understand how the Handwriting Assistive Device can best be used for children with writing difficulties. One Handwriting Assistive Device will also be given to the Mackay School at the end of the study.

Potential risks and Inconveniences associated with your participation

There are no risks associated with the study. However, we are asking you to share with us some confidential information, and you may feel uncomfortable talking about some of the topics. You do not have to answer any question or take part in the discussion/interview if you don't wish to do so, and that is also fine. You do not have to give us any reason for not responding to any question or for refusing to take part in the interview.

Access to results at the end of the study

At the end of the study, you may have access to the results if desired.

Confidentiality of Information

All personal information gathered about you and your child during the study will be coded to ensure its confidentiality. Only the members of the research team will have access to it. Any published results will be presented with complete anonymity. Any personal data, e.g. address, telephone number etc., will be kept in a separate file folder, accessible only to the researcher responsible for the project. This information will be kept for 5 years after the data collection period in a locked filing cabinet in the researcher's laboratory. It will be destroyed at the end of this period. Likewise, all the data recordings will be kept for 5 years after completing the data collection, after which it will be destroyed. However, for quality control of the research project, your research record could be accessed by a person authorized by the REB of the CRIR facilities or by the Ethics Unit of the Department of Health and Social Services of Quebec, which both adhere to a policy of strict confidentiality.

Videotaping/ Photography

It is possible that the entire session with the parent would be recorded through Teams or Zoom. We would use these with your permission for research purposes (presentations, scientific articles).

Do you authorize us to use the photographs or video recordings for research purposes?

☐ YES ☐ NO

Voluntary participation and withdrawal

Your participation in the above-described study is free and voluntary. You may withdraw from the study at any time without prejudice. Refusal to participate in the study will not result in any penalty or loss of benefits. If you withdraw from the study, all research data concerning your participation can be destroyed at your request.

Future research studies

The results collected from this study might lead to another research study to develop the Handwriting Assistive Device. If this is the case, do you authorize the project investigators to contact you again invite you to participate in a subsequent study?

☐ YES, FOR ONE YEAR ☐ YES, FOR TWO YEARS

☐ YES, FOR THREE YEARS ☐ NO

Responsibility of the Research Team

By accepting to participate in this study, you do not renounce any of your rights, nor do you release the investigators, the sponsor, or the institutions involved from their civil or professional responsibilities

Questions Concerning this Study

If you have questions concerning your rights or participation in this research project or you would like to withdraw from the study, please communicate with Antony Shruti Predhep, MSc student: antony.shruti@mail.mcgill.ca or 438-985-9967 with Philippe Archambault, philippe.archambault@mcgill.ca supervisor who can be reached at either 450 688-9550 ext. 4832 (lab) or 514 398-7323 (office).

If you have any questions regarding your rights and responsibilities or your participation in this research project, you may contact Ms. Coralie Mercerat, Research Ethics Coordinator for the CRIR's institutions 514-527-9565, extension 3789 or by email at the following email address: coralie.mercerat.ccsmtl@ssss.gouv.qc.ca.

You may also contact the Service Quality and Complaints Commissioner – CIUSSS du Centre-Ouest-de-l'Île-de-Montréal at (514) 340-8222 (ext. 24222) or by email at ombudsman.ccomtl@ssss.gouv.qc.ca

CONSENT FORM

I state that I have read and understood this study, the nature and extent of my participation, and the benefits and risks involved, for which I and they will be exposed, as illustrated in this form. I agree that I have had the opportunity to ask questions about the study and have received satisfactory answers.

I voluntarily agree to participate in this study. I can withdraw myself from this study at any time, without any questions asked. I certify that I have had adequate time to consider my decision.

A signed copy of this consent form will be given to me.

NAME OF PARTICIPANT (print) SIGNATURE OF PARTICIPANT

_____ _____

Signed at _____, the _____, 20___.

RESPONSIBILITY OF THE PRINCIPAL INVESTIGATOR

I, _____ certify that I have

1. explained the study to the participant,
2. answered the questions regarding this study,
3. explained clearly about his/her's child's voluntary participation and free-will for the withdrawal of participation in the research study stated above.
4. that I will give him/her a signed and dated copy of this form.

_____

Signature of the Principal Investigator or representative

Signed at _____,the_____,20__.

APPENDIX B

Questions for parents of children with writing difficulties

Initial assessment

1) Participant name:
2) Location:
3) Child's name:
4) Child's Date of Birth:
5) Child's Gender:
6) Relationship to the child:
7) Diagnosed impairment:
8) If it's CP
    a. Which type of CP your child has and can you elaborate on his/her associated difficulties?
    b. If your child has spastic CP, how severe it is?
    c. MACs and its level
9) If it's dysgraphia
    a. Which type of dysgraphia your child has and can you elaborate on his/her associated difficulties?
10) What are the assessments been used on the child? When does it taken place and what are the outcomes?

Semi-structured interview

Questions on facilitating conditions focusing on home, school and social context (Cook & Polgar, 2014; Venkatesh et al., 2003)

1) What age-appropriate activities your child can perform? Also elaborate on the activities that are challenging for him/her?
2) How does he/she feel about writing?
3) Does he/she have difficulty independently initiating, sustaining, or completing the writing task?
    - Probes : Did that affect your academics? Can you brief on the difficulties you faced during tasks at school, assignments? Did the school provide you with any support or external resources? Do the difficulties in writing hinder your relationship with your peers or family? Did it affect your sense of identity/motivation?
4) How well can he/she perform writing in a scale of five?

5) What kind of help does the child need to do his or her writing, how much help, and how often it is needed? This includes their ability to hold the pencil and manipulate it, as well as the capacity to plan, remember and execute movements. Also consider the child's coordination, dexterity, and integration of sensory input.
6) What type of grasp does he/she use for writing?
7) How much discomfort does he/she experience while writing in a scale of five?

After viewing the HAD video

8) Performance expectancy (Venkatesh et al., 2003)
How do you perceive the HAD and it's impact on your child?
- Probes: Will it improve his writing performance? Will it make the writing easier on him? Will it decrease the time needed to write?

9) Effort expectancy (Venkatesh et al., 2003)

How do you find the HAD's flexibility with your child?
- Probes: Will be easy to operate? Will it be easy to become skillful with the HAD? Or will it take too long to use the HAD? - Complexity and ease of use

10) Effort expectancy (Venkatesh et al., 2003)
Do you think your child can use the HAD to draw/write?

11) Social influence (Venkatesh et al., 2003)
Will your child enjoy his writing experience, if he has HAD?
- Probes: Does using the HAD make it good/bad idea? Will it be fun for the child? Will it make his writing more interesting?

12) Attitude towards using technology (Venkatesh et al., 2003)
Will the HAD be intimidating to your child?

13) Use behaviour (Venkatesh et al., 2003)
What strategies would you suggest engaging in if your child finds it frustrating/challenging?

14) Use behaviour (Venkatesh et al., 2003)
What comments or questions do you have for the future HAD design?

Questions for individuals with writing difficulties

Initial assessment

1) Participant name:
2) Residence:
3) Individual's name:
4) Individual's Date of Birth:
5) Individual's Gender:
6) Diagnosed impairment:
7) If it's CP
    a. Which type of CP do you have, and can you elaborate on your associated difficulties?
    b. If you have spastic CP, how severe is it?
    c. Have you taken MAC (Manual Ability Classification System)? If so, can you tell me the level you belong?
8) If it's dysgraphia
    a. Which type of dysgraphia you have, and can you elaborate on y associated difficulties?
9) What assessments have been used on you, when you were a child and what are the outcomes?

Semi-structured interview

Questions on facilitating conditions focusing on home, school and social context (Cook & Polgar, 2014; Venkatesh et al., 2003)

10) How did you feel about writing when you were a child?
11) Did you have difficulty independently initiating, sustaining or completing the writing task?
12) What kind of help did you need to write when you were a child, and how much help and how often it was needed?
    - Probes : Did that affect your academics? Can you brief on the difficulties you faced during tasks at school, assignments? Did the school provide you with any support or external resources? Do the difficulties in writing hinder your relationship with your peers or family? Did it affect your sense of identity/motivation?
13) How was your experience with not having to use any devices/software to write while you were in school?

After viewing the HAD video

14) Performance expectancy (Venkatesh et al., 2003)
How do you perceive HAD and its impact?

- Probes: Would it have improved your writing performance while you were a child? Will it make writing easier for you?

15) Effort expectancy (Venkatesh et al., 2003)

How do you find the HAD's flexibility?

16) Effort expectancy (Venkatesh et al., 2003)

Is the HAD easier to operate? Will it be easy to become skillful with the HAD?

17) Social influence (Venkatesh et al., 2003)

What do you think of the social influence associated with HAD to write?

18) Attitude towards using technology (Venkatesh et al., 2003)

19) Will the HAD be intimidating to your younger self?

- Probes: Does using the HAD make it a good/bad idea? Would it have made your writing experience more fun and interesting?

20) Use behaviour (Venkatesh et al., 2003)

If you could have used HAD as an early intervention, what age would have been appropriate to use?

21) Use behaviour(Venkatesh et al., 2003)

What comments or questions do you have for the future HAD design?

APPENDIX C

Coding dictionary

1 THEME: Child related factors

Definition: Experiences such as skills, abilities and challenges related to the childhood.

1.1 Category: Abilities and impairments

Definition: Illustrates the child's overall skills and difficulties in their everyday life.

1.1.1 Gross motor skills
1.1.2 Fine motor skills
1.1.3 Impairments
1.1.4 Perceptual motor skills
1.1.5 Cognition
1.1.6 Spatial orientation

1.2 Category: Writing related factors

Definition: Demonstrate the child's competencies and challenges in different factors of writing.

1.2.1 Pencil grasp
1.2.2 Drawing skills
1.2.3 Writing skills
1.2.4 Expressive writing
1.2.5 Physical and mental exhaustion

1.3 Category: Social context

Definition: Illustrates a picture of their environment on how supportive and challenging for a child's development.

1.3.1 Clinical interventions
1.3.2 Institutional support/challenges
1.3.3 Family Support

1.4 Category: Habilitation and Rehabilitation

Definition: Elaborates on their with experience with compensatory strategies, interventions and assistive technologies.

1.4.1 Writing strategies
1.4.2 Writing Rehabilitation programs
1.4.3 Use of Low-Tech AT
1.4.4 Use of High Tech AT
1.4.5 Struggles with AT

1.5 Category: Perception towards writing and technology

Definition: Demonstrates their experience with technology on writing.

1.5.1 Attitude towards writing
1.5.2 Importance of writing
1.5.3 Attitude towards AT
1.5.4 Ideal solution

2 THEME: HAD related factors

Definition: Perspectives on the different features and factors of HAD have been expressed.

2.1 Category: User acceptance and Accessibility of HAD

Definition: General opinions and suggestions about the HAD design for acceptability and accessibility have been demonstrated, to deliver quality and effective experiences for children's with writing difficulties.

2.1.1 Size
2.1.2 Portability
2.1.3 Rotatory arm
2.1.4 Pencil handle
2.1.5 Dampers
2.1.6 Ease of use
2.1.7 User-friendly
2.1.8 Suggestions for improvement

2.2 Category: Expected use of HAD

Definition: Elaborates how parent's view the HAD and the potential benefits they could think of, in terms of a child's writing experience.

2.2.1 General benefits
2.2.2 Mode of action
2.2.3 Early intervention
2.2.4 Strategies
2.2.5 Willingness to try

2.3 Category: Interpersonal and social factors

Definition: Explores the personal and societal feelings of participants around the HAD.

2.3.1 Attitude towards the performance expectancy of the HAD
2.3.2 Attitude towards HAD
2.3.3 Perceived stigma
2.3.4 Solutions/strategies