# Exploring the Use of Assistive Robotics in Play and Education for Children with Disabilities

by

Negin Azizi

A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Master of Applied Science
in
Electrical and Computer Engineering

Waterloo, Ontario, Canada, 2022

## Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

## Statement of Contributions

This thesis includes first-authored peer-reviewed material that has appeared in the conference proceedings of IEEE Ro-Man, and accepted for publication in another upcoming conference, the International Conference on Social Robotics (ICSR2022).

**Research presented in Chapter 3 (Study 1)**

Negin Azizi, Dr. Shruti Chandra, Mike Gray, Melissa Sager, Dr. Jane Fane, and Prof. Kerstin Dautenhahn designed the study. Negin Azizi and Mike Gray implemented the apparatus, Mike Gray and Melissa Sager performed the experiment, Negin Azizi conducted the data analysis, and drafted the manuscript. Dr. Shruti Chandra, Mike Gray, Melissa Sager, Dr. Jane Fane and Prof. Kerstin Dutenhahn reviewed and edited the manuscripts, Dr. Shruti Chandra, and Prof. Kerstin Dautenhahn supervised the project.

> *Citation:*
> Negin Azizi, Shruti Chandra, Mike Gray, Melissa Sager, Jennifer Fane and Kerstin Dautenhahn, "An Initial Investigation into the Use of Social Robots within an Existing Educational Program for Students with Learning Disabilities," 2022 31st IEEE International Conference on Robot and Human Interactive Communication (RO-MAN), 2022, pp. 1490-1497
> DOI: doi: 10.1109/RO-MAN53752.2022.9900735.

**Research presented in Chapter 4 (Study 2)**

Negin Azizi, Dr. Shruti Chandra, Mike Gray, Dr. Jane Fane, Melissa Sager, and Prof. Kerstin Dautenhahn designed the study. Negin Azizi and Mike Gray implemented the apparatus, Mike Gray and Jane Fane performed the experiment, Negin Azizi conducted the data analysis, and drafted the manuscript. Dr. Shruti Chandra, Mike Gray, Dr. Jane Fane, Melissa Sager, and Prof. Kerstin Dautenhahn reviewed and edited the manuscripts, Dr. Shruti Chandra, and Prof. Kerstin Dautenhahn supervised the project.

> *Citation:*
> Negin Azizi, Shruti Chandra, Mike Gray, Jennifer Fane, Melissa Sager, and Kerstin Dautenhahn. 2022. User Evaluation of Social Robots as a Tool in One-to-one Instructional Settings for Students with Learning Disabilities. Accepted for conference presentation and publication in proceedings of *International Conference on Social Robotics, ICSR 2022.*

**Research presented in Chapter 5 (Study 3)**
Dr. Melanie Jouaiti and Prof. Kerstin Dautenhahn designed the study. Negin Azizi and Melanie Jouaiti performed the experiment. Negin Azizi, Dr. Melanie Jouaiti, and Kevin Fan conducted the data analysis. Negin Azizi, Dr. Melanie Jouaiti, and Kevin Fan drafted the manuscripts. Dr. Melanie Jouaiti and Prof. Kerstin Dautenhahn reviewed and edited the manuscripts, and also supervised the project.

> *Citation:*
> Negin Azizi, Kevin Fan, Melanie Jouaiti, and Kerstin Dautenhahn. 2022. Play Dynamics in a Collaborative Game With a Robot as a Play-Mediator. Accepted for conference presentation and publication in proceedings of *International Conference on Social Robotics, ICSR 2022.*

**Abstract**

Assistive technologies in general, and assistive robots in particular, are being studied extensively to maintain and increase the capabilities of individuals with disabilities. However, there are aspects in this field that have not been explored yet. This thesis investigates the use of assistive robots for different groups of children with disabilities, such as learning disabilities, and upper-limb disorders, where the use of robots as tools have not been widely explored. We began by exploring learning disabilities and their challenges.

Students with a learning disability (LD) generally require supplementary one-to-one instruction and support to acquire the foundational academic skills learned at school. Because learning is more difficult for students with LD, students can frequently display off-task behaviours to avoid attempting or completing challenging learning tasks. Re-directing students back to their learning task is a frequent strategy used by educators to support students. However, there have been limited studies investigating the use of assistive technology to support student re-direction, specifically in a "real-world" educational setting. We investigated the impact of integrating a socially assistive robot to provide re-direction strategies to students. A commercially available social robot, QT, was employed within the existing learning program during one-to-one remedial instruction sessions.

First, we conducted a pilot study to explore the impact of the robot on students' on-task behaviours and progress towards learning goals. The results of our mixed method analysis suggest that the robotic intervention supported students in staying on-task and completing their learning goal.

Learning from the lessons of the pilot study, we designed a between-participant study with two conditions, control, and intervention with the QT robot to address the shortcomings of the pilot study. In the main study we aimed a) to evaluate the acceptance of the social robot by the users, i.e., instructors and students in a real-world educational setting; and b) understand the impact of the robot's intervention on student's engagement during learning tasks over multiple learning sessions. Our qualitative analysis suggests that instructors and students showed positive attitudes towards the social robot in their one-to-one sessions. In addition, the students were more engaged with their task in the presence of the robot, and displayed fewer off-task behaviours in the intervention condition, compared to the control condition. These results suggest that a social robot can be used as an effective educational tool for instructors in boosting engagement and mitigating off-task behaviours for students with learning disabilities.

Assistive technology can also be beneficial in play, especially for children that face barriers in physical activities due to their physical impairments. In the third study, we focused on children with upper-limb disorders and the lack of equipment and enjoyable experiences in games. While game-play is widely used in human robot interaction studies, using a robot as a play-mediator, where two individuals interact with each other through a robot, has not been fully studied yet. However, understanding the play dynamics of this type of game is an important step towards designing an engaging experience.

In this work, participants played two collaborative games which involved teleoperating a mobile robot. Each game consisted in achieving the same task, but involved two different collaboration strategies: one where the players shared tasks and one where joint action was necessary. In this study, we focused on how both players collaborated with each other in terms of coordination and communication using video and joystick data. Due to Covid-19 restrictions, we were not able to recruit children with physical disabilities. Instead, we recruited university students to participate in the study to collect data. Results indicated different behavioural events, and observed different levels of communication among the two conditions.

The present work contributes to robotic assistive technologies by providing support for children with learning disabilities and upper-limb disorders in different aspects of their life, such as education and play.

## Acknowledgements

I would like to express my deepest appreciation to my supervisor, Prof. Kerstin Dautenhahn, for her helpful information and practical advice, throughout my research and writing the thesis. I would like to thank my co-supervisors, Dr. Shruti Chandra and Dr. Melanie Jouaiti, and our colleagues at the Learning Disabilities Society, Mike Gray, Jennifer Fane, and Melissa Sager, for their help and advice.

I am also grateful to my thesis review committee, Prof. Shi Cao and Prof. Oliver Schneider, for their precious time to review my thesis and providing valuable feedback.

I appreciate all the support I received from family and friends.

## Dedication

This is dedicated to my parents, Mostafa and Minoo, and my sister, Nazanin, who have always taught me to work hard, and who supported me throughout the process.

# Table of Contents

# List of Figures

# List of Tables

# Chapter 1

# Introduction

The term "assistive technology" (AT) refers to any item, equipment, and device used to enhance or maintain the capabilities of individuals with disabilities [1] [2, 104]. Assistive technology can sometimes be more beneficial for Children with disabilities than adults, due to children's developmental potentials [32]. More specifically, assistive technology can benefit children with special needs in communication, mobility, and self-care, by enabling them to explore different aspects of life such as family relationships, friendships, education, and play. This leads to the development and inclusion of children in society, and therefore enhances their quality of life [16]. Research supports the benefits of various assistive technologies such as computer-based instructions, videos, word processing tools, and robots [70, 34, 1].

Robots, coming in different forms, are increasingly being used to assist children who have disabilities and need extra help [36, 64], in play and academic areas [26]. Robots can assist humans by interacting with them within two contexts: social and physical interaction. Manipulation, haptics, medical, and rehabilitation robots fall under physical interaction. Whereas, social robotics and socially assistive robots include interactions involving verbal and nonverbal expressions and communication [38, 37].

## 1.1 Motivation

This section entails some challenges and gaps in using assistive technology in play and educational areas, for children with special needs. While research in the field of robot-

[1] We used the term "disabilities" in this thesis rather than "special needs" since the former is commonly used in Canada [65]

assisted therapy for children with autism has received a lot of attention, there are other conditions that might benefit from robotic interventions, that have not been investigated widely. We discuss the motivations for doing research in two specific fields of learning disabilities and upper-limb disorders in the following subsections.

The following topics entail the related problems in the field of learning disabilities and assistive technology.

### 1.1.1 Learning disabilities

The term Learning Disabilities (LD) refers to a heterogeneous group of disorders relating to difficulties in the acquisition and use of language, reasoning, or mathematical abilities [109]. These difficulties are the result of brain-based differences that cannot be explained by an intellectual or developmental disability, vision, hearing, or motor skill problems, nor cultural, structural, or economic reasons [50].
LD can be identified by an inconsistency between students' educational level and intellectual abilities, often viewed as "unexpected under-achievement" and diagnosed through testing [71]. Studies have demonstrated a co-morbidity rate of up to 41% between LD and other brain-based differences, such as Attention-Deficit/Hyperactive Disorder (ADHD) and executive dysfunction in children, which exacerbates challenges for many learners [35]. Due to these learning differences, students frequently struggle to sustain focus on a learning task and often demonstrate behaviours called *off-task behaviours* such as shutting down, discussing off-topic subjects, or refusing to work on a task [76].

#### 1.1.1.1 Personalized learning for students with LD

Students with LD have unique learning needs and greatly benefit from individualized support. Thus, tailoring instruction to each individual's needs and uniqueness is part of any effective educational program [71, 77]. Individualized learning, which often takes place in the context of one-to-one instruction, is most successful if the method adapts to the learner's specific needs [107], most notably addressing the challenges learners with LD face.

#### 1.1.1.2 Redirection Strategies for students with LD

Educators use redirection strategies (RS) to help students stay on-task when learning becomes difficult. These strategies reduce students' negative experiences with challenging learning tasks. RS may include various types of physical activities that can decrease off-task behaviours, such as breathing exercises, dancing, or running in place [110, 79, 122].

#### 1.1.1.3 Social Robots in education

Social robots have been investigated widely in the field of education to support children with special needs [87]. Research in the field of child-robot interaction suggests that children are more engaged when interacting with a social robot [62]. Robots have been exploited to play different roles in educational scenarios as a teacher, monitor, peer, or learner [51].

#### 1.1.1.4 Assistive technologies for learning disabilities

In recent years, educators have explored the use of social robots to support learning for students with or without disabilities [108, 60]. However, most of the research in the therapeutic context is focused on children with Autism Spectrum Disorder (ASD) [60].
Although mobile applications and assistive technologies have been used to assist students with LD [56], few studies have investigated the impact of social robots on children with LD [99].

#### 1.1.1.5 Real-world Experiments

Most studies in the field of child-robot interaction design a scenario and then recruit participants with specific conditions and within a narrow age range. Commonly, research studies in social robotics are conducted in controlled environments such as laboratories and use technologies (e.g. robots) which are controlled by a technician or a human researcher with expertise in that specific technology [59, 27]. However, in order to use robots in real-world applications, we need to understand the utility of robots across many "real world" scenarios and their ability to tailor support and interventions for participants with different ages, needs, and conditions.
Socially assistive robots have not been explored for students with LD, especially in long-term interventions in real-world settings. Additionally, despite the possible advantages of assistive technology, educators are infrequently trained or supported in using assistive technology, yet are expected to become experts in their usage [5].

#### 1.1.1.6 Users' attitude toward using social robots

Research has shown that social robots can be effective for students with disabilities, albeit limited research has been done on the instructors' attitude toward using robots in special education [33]. Thus, there is still a great need for more research on the acceptance of social robots from both the student and educator perspectives. Technology acceptance, in particular in in-situ/field studies, are important steps towards illuminating how social robots could be used in real-world applications for children with disabilities, cf. [103].

### 1.1.2 Coordination and Upper-limb disabilities

Developmental Coordination disorder (DCD), defined by gross motor impairments, affects children in physical activities [20]. In this research, we focused on upper-limb disorders. Grasping and manipulating objects are some challenges these children face in their daily life [15]. They also show difficulties in play and games, especially those requiring physical movements [54, 18].

#### 1.1.2.1 Robots in play

Play is a widely used element in Human-Robot Interaction (HRI) experiments [41, 47, 52, 63], as it provides an enjoyable and clearly structured context. Play is also paramount for child development [14], as well as for enjoyment, and has therefore been studied extensively in child-robot interaction [80], including robots as tutors or game partners for pairs of children, e.g. [22, 117], or as a referee for pairs of adult participants [114]. However, only a few studies explored using a robot to mediate play between two participants [85], whereby the robot serves as a medium rather than an autonomous agent.

In order to facilitate play for children with upper limb impairments, the design of the MyJay robot as a play-mediator was previously reported [74]. The main goal of MyJay robot is to enable children to play with their peers through the robot and to provide a fun, motivating, and engaging experience for the children, despite the challenges they face [74]. To do so, it is important to understand the play dynamics of how two people can play with MyJay.

## 1.2 Research Goal

This thesis aims to investigate the use of robots as assistive technologies within educational settings and play scenarios by conducting three experiments with different groups of human participants. In all experiments, a robot is used as an assistive tool to assist the users. While the robot has different functionalities and interacts within different contexts with users in each study, the role of the robot, as a tool, is common among all three experiments. In the first and second study, the robot is used by instructors as a tool to assist students, and in the third study, the robot is a tool for users to play through it (the robot as a mediator). Dautenhahn (2007) reviewed definitions of social robots, which can range from socially evocative to socially intelligent [29]. According to a recent definition, "Social robots are designed to interact with people in human-centric terms and to operate in human environments alongside people, Many social robots are humanoid or animal-like in form. Social robots engage people in an interpersonal manner, communicating and coordinating their behaviour with humans through verbal, nonverbal, or affective modalities." [17] Thus, social robots are not necessarily fully autonomous, and they do not necessarily need to have a high degree of intelligence. Since the robots in our research are used as tools and are not designed to replace therapists or instructors, they were not fully autonomous and did not have many 'intelligent' behaviours. They were programmed to be used as mediators within the designed interactive scenarios.

In the first study [7] (presented in Chapter 3), we conducted research in a "real-world setting". We designed an in situ study, using a social robot in collaboration with a non-profit educational, charitable organization that specializes in research-based, one-to-one instruction for children and youth with Learning Disabilities. A field study design was used to explore the feasibility and value of integrating a social robot into an existing educational program, through specialized LD instructors without experience using social robots. Collaboratively, we developed a social robot protocol as a tool for instructors to use in their regularly scheduled one-to-one instructional sessions for students with LD[2]. The social robot and protocols were integrated into the one-to-one sessions with no change to students' learning goals, session foci, or curriculum, and without the university-based research team present. The robot acted as a moderator/helper to students, where instructors would initiate pre-programmed routines for the robot to perform via a tablet as they

[2]While learning disability (LD) is the correct clinical and legal term, many organizations (including the one that participated in this study) prefer to use the term learning difference to denote that all learners have strengths and challenges and that strength-based language is an important way to shift the negative perception of neurodiversity.

saw appropriate. Our participants did not belong to a group with a specific LD. Instead, our system was created to work within the existing instructional format of all participants' one-to-one sessions and integrated within each student's learning and session goals.

In our in situ study, we designed and implemented an application interface that would guide the instructors through the typical phases of instruction to easily navigate through the interface with minimal experience and without requiring technical expertise. The study comprised of two phases, an "Instruction As Usual" (IAU) and a "Robot-Mediated Instruction" (RMI) phase, where the instructors could use the social robot as a tool to moderate some parts of the session and provide redirection strategies to students appropriate for their learning goals.

The results of the first study indicated that the intervention supported students in staying on-task, however, there were limitations related to the study design, such as the technological complexity of the instructional protocol and the absence of a control group. Building from the first work, we designed the second study, an expanded scope of the first study that aimed to investigate how students with LD are impacted by a social robot as an instructional tool and assessed the acceptance of the robot in one-to-one lessons as part of an in-situ study. Different from the first study, students were assigned to either a control or intervention condition.

The second study [6] (Chapter 4) focused on developing an instructional protocol for the use of a social robot during one-to-one instruction for students with LD. The protocol can be used for students with a range of learning difficulties and can be employed in individualized student learning interventions without any alteration of their program. The aim of the study was to explore the integration of a social robot as an assistive tool for instructors, providing redirection strategies in a one-to-one instruction setting with children with LD.

The third research study [8] (Chapter 5) focuses on using social robots for children with special needs in play. Due to lack of equipment, children with upper-limb disorders have difficulty in play. They face barriers in using a joystick, due to their movement distortion. To address this difficulty, in another project, we had collected data from children with upper-limb impairments while they were playing a game. They navigated a simulated robot through a maze, using an adaptive joystick that was specifically designed for them. This experiment was done to design a joystick that can compensate the movement distortion of children [58]. In the next step, we aimed to study the play dynamics of children, however, due to Covid-19 restriction in recruitment and participation of these children, we started our data collection by recruiting adults. The final goal of our project was to design a game for children with upper-limb disorders using the special joystick designed in the other project described.

As a first step to understand the dynamics of how two people can play with the MyJay robot, we investigate play dynamics of pairs of adult participants playing a game through MyJay. In particular, we study how different kinds of collaborative games influence how players collaborate and communicate with each other. In our experimental design, two participants controlled the same robot, each using a joystick. In the *Shared* condition, the participants were each responsible for different functionalities of the robot, facilitating turn-taking. In the *Fusion* condition, the robot answered to commands, if and only if both players agreed on the next course of action, i.e. gave the same command at the same time. Thus, in this condition, coordination between the players is paramount.

## 1.3 Summary of Contributions

The main contributions of this research are:

- The first study integrated a social robot into an already existing program[3] for students with LD. In this field study, we did not change the goals of the instructional program or the curriculum. Instead, we integrated the robotic intervention into a wide range of students' programs to accommodate the various scenarios and situations that students and instructors may face in a typical instructional session. Our participants did not belong to a group with a specific LD. Instead, our system was created to work within the existing instructional format of all participant's one-to-one sessions and integrated within each student's learning and session goals.

- The second study, an expanded version of the previous study, investigates student engagement in the presence of a social robot, exploring perceptions of instructors and students during robot-mediated sessions. The contributions of this study are as follows: 1) the integration of a social robot into an already existing program without changing the learning goals or curriculum; 2) user evaluation using the technology acceptance model for the application of socially assistive robots in a real-world educational setting as part of a long-term study; 3) development of the robotic system (a system with a variety of activities compared to the previous study) to meet the expectations of students and instructors, and consider their various needs.

- The third study investigates the patterns and dynamics of two players, in a collaborative game with a robot as a play mediator, controlled by joysticks. The study

[3] In the existing program, students work one-to-one with a qualified instructor on an ongoing basis to improve student independence, confidence, and academic success.

allows us to design a more enjoyable game, by studying the play dynamics and different collaborative strategies of two players, and can further aid us in designing play scenarios and therapy settings for children with upper-limb challenges.

## 1.4 Thesis Overview

The rest of this thesis is structured as the following chapters. Chapter 2 entails a literature review on the different topics of relevance, such as learning disabilities, individualized learning, social robots in play and education, etc. Chapter 3 present our first experimental study, that explores the use of social robots within an existing educational program for students with learning disabilities. Chapter 4, expands on the first study, by presenting another experimental experiment to evaluate the users' perception toward using a social robot as a tool in instructional lessons. Chapter 5, targets a different population, describing the dynamic patterns of users while playing a collaborative game with a social robot. Finally, the last chapter, Chapter 6, gives a conclusion of all the studies corresponding to the research questions. Appendix A includes the ethics application, Appendix B, and Appendix C includes the questionnaires in each study.

## 1.5 State of Contribution

This thesis includes three experiments, and the term "we" was used throughout this thesis to show that the studies were part of teamwork (as it is common in human-robot interaction experiments). I was leading the conceptual and technical development part of the first two studies, and was responsible for the data analysis and lead author drafting the resulting publications. I contributed to the preparation of the third study, was in charge of running the experiment, and major parts of data analysis, as well as drafting the resulting submission.

# Chapter 2

# Background

This chapter, delves into the topics related to the targeted groups (learning disabilities and upper-limb disorders) and provide background knowledge relevant to the experimental design of each experiment. The first section of this chapter, delves into the major topics of the first and second study. The second section, introduces main aspects of research, related to the third study.

## 2.1 Learning Disabilities

Learning disabilities (LD) is a heterogeneous life-long condition that includes a range of disorders that may affect the acquisition, retention, or understanding of verbal or non-verbal information. Students with learning disabilities struggle with specific academic skills such as reading, writing or math, but otherwise demonstrate normal intellectual functioning [19, 53]. Students with LD often have a low sense of self-efficacy and difficulty self-regulating themselves in an academic context, which can negatively affect their learning [97]. In addition to academic underachievement, students with LD frequently face social, emotional, and behavioural problems as a result of repeated learning challenges and perceived failures [48]. Having LD is a lifelong condition, and individuals need to acquire skills to overcome or manage challenges [46].

Students with various disabilities require differentiated and individualized treatment, which can include curricular adaptations, personalized action plans, contingency plans, and speech therapy [57]. Personalized learning plans can offer strategies that address learning challenges [69] and allow students to make sustained progress towards foundational academic skill gaps. Students with LD require personalized instruction that consider their learning differences and targets their unique challenges [71]. Students with LD frequently struggle to stay focused on a task, and exhibit off-task behaviours such as work refusal, fidgeting, and off-topic conversations.

Redirection strategies aid in mitigating off-task behaviours and help students stay on-task and make sustained academic progress[9]. Examples of these strategies include movement breaks, positive self-talk, and breathing exercises. [110].

### 2.1.1 Individualized Learning for students with LD

Individualized treatment and intervention play an important role in diminishing the impact of an LD [48, 5]. The most common treatment is specialized education and instruction, which requires individualized or small group settings to build on strengths and address foundational skill gaps through practice and consistent feedback [113]. Advances in technological tools and assistive technologies can offer students and educators personalized educational systems that adapt to the individual differences [12]. One-on-One interventions can benefit students with LD by targeting their needs in the delivery of instructions [113]. Technologies such as speech synthesis, organizational software, and voice recognition programs can benefit students with LD and help them in reading, and writing [39, 102], when they are personalized and carefully used [89].

### 2.1.2 Social robots in learning

Socially assistive robotics (SAR) is a field that targets helping caregivers, clinicians, and educators with personalized interventions using robot [24]. SAR focuses on using a social robot to aid humans in the areas such as education and healthcare [23, 105] mainly through social interaction, without any physical human-robot contact. Some studies focused on teaching educational skills to students [111], while others have targeted teaching social and communication skills [95]. SAR has been widely used in the treatment of children with ASD, e.g. for teaching social, emotional, and cognitive skills in a play-based scenario. For example, [121] conducted a study with the Nao robot teaching social rules through games to both typically developing children and children with ASD. Little research has been done using SAR for people with LD, specifically, in the context of academic instruction [60].

Several studies support the effectiveness of using social robots for learning, as they have the potential to deliver an engaging learning experience tailored to the student's learning styles and needs [23, 11, 72]. Research has shown that robot-assisted therapy can benefit students with special learning needs [3], such as LD. For example, [86] proposed a machine-learning-based method to measure the engagement of children with LD while interacting with a robot during an educational session. A long-term study evidenced that a social robot, Kaspar, was an effective tool to assist children with Autism Spectrum Disorder. Teachers used the robot in their day-to-day activities in a real-world environment, a nursery school, in the absence of the research team [103]. Robots have also been developed to provide robot-assisted play to mitigate the barriers that children with physical disabilities experience [112]. For example, the MyJay robot, an open-source mobile robot, was created to investigate robot-mediated play for children with upper limb challenges [74]. To do this, a user-centred design study was conducted to elicit users' feedback for designing a robot that could mediate child-child interaction [73].

The few studies in this area include[86] who explored a model estimating the engagement of children with LD interacting with a robot and [66] who investigated the use of a social robot to improve visual motor skills in children with LD. A more recent study, [60] was conducted to assist children with LD in their reading tasks through human-robot interaction.

### 2.1.3 Perspectives toward using social robots

Research has shown that social robots can be effective for students with disabilities, albeit limited research has been done on the instructors' attitude toward using robots in special education [33]. Thus, there is still a great need for more research on the acceptance of social robots from both the student and educator perspective.

Technology acceptance, in particular in in-situ/field studies, are important steps towards illuminating how social robots could be used in a real-world applications for children with disabilities, cf. [103].
SAR can offer more engaging learning experiences and provide personalized support to help students' engagement [60]. Investigation of the technological acceptance of SAR is crucial, specifically, when it is used in real-world settings.

## 2.2 Upper-limb Disorders

Developmental Coordination Disorder (DCD) a neurodevelopmental condition, affecting motor coordination and Upper-limb disorders, are physical health conditions, affecting arms, hands, and fingers. Individuals are born with these conditions that range from mild to severe [81]. DCD is a prevalent disorder in Canada, affecting 2% to 5% of children [20]. While DCD is sometimes overlooked, it considerably impacts children's lives, at school and home [61]. Adaptive solutions, can assist children with upper-limb disorders compensate their differences [81].

### 2.2.1 Upper-limb Disorders and Play

Their physical condition is a barrier to lots of play activities, and the majority of children with DCD are not active in playgrounds. As children with DCD are less physically active, have their own patterns of play [90]. They don't get involved in social physical play and spend more time alone [100]. Several studies have explored using serious games, in rehabilitation and therapy [83], However, there's been limited research on games requiring physical activities for people with upper-limb injuries. For example, Amorim et al. reviewed works investigating serious games for stroke rehabilitation of upper-limb [4], mentioning the potential use of VR in serious games in this field [123].

### 2.2.2 Play and social robots

Play is especially important in the context of therapy, as it maintains motivation and engagement. Social robots are still scarce in the literature related to upper limb rehabilitation. One study [119] used the Cozmo robot robot as a motivator in the therapy exercises, as the robot reacted positively when the children performed the required therapy, correctly. Another study [49], designed a Pacman-like game with small graspable mobile robots to encourage children to perform grasping and manipulation tasks.

Tasevski et al. designed a robot that was meant to increase the motivation of the children [106]. Their robot improved non-verbal communication, gestures, and verbal production. Fridin et al. observed that children with cerebral palsy were more involved in the therapy when using the Nao robot to carry out repetitive training [42]. The robot provided feedback and adapted the exercises based on performance. Another study considered if the Ursus robot could adapt the exercises to each participant, while monitoring and learning from the interaction, thanks to the proposed cognitive architecture [21]. They reported increased collaborative behaviours from the children interacting with the robot.

### 2.2.3 Collaborative games

In previous works, the differences between collaborative versus competitive gameplay have been studied in educational [93] and therapeutic [82] settings. Novak et al. showed that participants preferred playing with a partner rather than playing alone. However, preferences in terms of competitive or collaborative gameplay differed across individuals, and most players liked one condition and disliked the other [82]. Sanchez et al. observed emerging competitive behaviours in a classroom setting and introduced an h-index like scoring policy to encourage cooperation amongst students. Arellano et al. compared physiological data in the case of solo, competitive and collaborative play. They reported that players experienced similar levels of arousal in individual and collaborative contexts [43]. Research supports that technology can possibly increase communication, collaboration, and coordination between people. Thus, designing tools as mediator to scaffold children's collaboration can be beneficial. Most of the works, in collaborative technologies, are designed to reach a learning goal, entertainment, etc [10].

### 2.2.4 Engagement, Enjoyment

Cognitive engagement can be defined more generally as one's cognitive willingness to take on the task at hand; this includes the amount of cognitive load and effort invested in the task and the persistence in completing the target task [92]. The understanding and measurement of cognitive engagement are paramount to the success of developing effective interactive systems. The concept of cognitive engagement is often applied in the domain of education, and child development [78].

Due to the importance of engagement metrics in many practical applications, measurement of engagement has been explored extensively. Generally, there are two categories of methods to measure engagement: self-reporting methods and non-self-reporting methods [120]. Self-reporting methods often employ questionnaires and/ or interviews to collect engagement data directly from the study participants. This type of method is usually low-cost and the data is relatively easy to analyze. However, study participants' subjective ratings of their engagement can be influenced by many factors, and their memory recall of experimental events can be inaccurate during the data collection phase; thus, self-reporting methods may be biased and provide unreliable data. On the other hand, non-self-reporting methods do not rely on the direct reporting of study participants, and are hoped to provide more objective data. Objective data are typically collected in real-time during the ongoing interaction. and are later analysed, either by manual annotation or automated processes. Non-self-reporting data can be visual, auditory or physiological [120, 91]. Some common physiological signals to evaluate effort and engagement include skin conductivity [88], pupil size [55], electroencephalogram (EEG) [13], heart rate[75] and many more. Thanks to recent advances in wearable health monitoring devices, the collection of heart rate data is becoming more and more accurate while being non-intrusive. Therefore, heart rate has been suggested as an effective signal to utilize for engagement measurement [68, 28, 98].

Ladino Nocua et al. utilized heart rate data to assess student engagement in distance learning during COVID-19 [68]. They performed heart rate collection with wearable Photoplethysmography (PPG) sensors. Heart rate data were labelled with different events, and the labelled heart rate series were clustered. Their results demonstrated that during active learning activities students' heart rate varied significantly compared to the baseline heart rate, and they confirmed that heart rate could be used as an effective measure of student engagement in distance learning.

However, the value of active learning seems unable to extend to lectures in actual classrooms. Darnell et al. unitized heart rate data to evaluate student engagement and attention focus during in-person active learning sessions [28]. The data collection was performed with wearable heart rate sensors (Mio alpha heart rate monitors). They inspected the rolling average of students' heart rates in 4 consecutive 50-minute lectures and found that active learning in class could not effectively increase student engagement or reset student attention; the true value of in-person active learning resided in the activities themselves.

Senthil and Wong studied the relationship between student engagement and student heart rate [98]. They collected data with the wireless heart rate sensor (Mio fuse sensor), and recorded the average resting heart rate and excited heart rate of each participant in the respective designed activities. Subsequently, they recorded each participant's heart rate during a one-hour lecture. Their results suggested that students with a higher grade point average (GPA) had their heart rate exceeding their excited heart rate levels more frequently than students with lower GPAs. Students with lower GPAs had stable heart rates throughout the lecture, and their heart rates were usually below their respective excited heart rates. Based on these results, they concluded that heart rate data is related to student engagement.

# Chapter 3

# Study 1: An Initial Investigation into the Use of Social Robots within an Existing Educational Program for Students with Learning Disabilities

This pilot study investigates integrating a social robot into an already existing program for students with learning disabilities, without any change to their curriculum, where instructors used the robot as a tool in their one-to-one lessons.

## 3.1 Research questions

Our goal was to answer the following research questions:

RQ1: Would the presence of the robot support on-task behaviours and learning goal completion for students?
RQ2: What impact did the RS provided by the robot have on redirecting the students' focus back on a challenging task?

The novel contribution of our work was the integration of a robot into an already existing program[1] for students with LD. In this field study, we did not change the goals of the instructional program or the curriculum, and integrated the robotic intervention into a wide range of students' programs to accommodate the various scenarios and situations that students and instructors may face in a typical instructional session.

## 3.2 App Design

For instructors to operate the robot effortlessly, we developed a separate web application interface to display the structure of the session on a single page for a smooth flow of interaction. The application was designed to give instructors complete control over the robot usage based on the general steps they followed during the RMI sessions. The app's main page reflected three parts of a session displayed as digital buttons: 1) Introduction Phase, 2) Working on goal, and 3) Goodbye. The robot was semi-autonomous, and the instructors selected the programmed behaviours of the robot, as they saw appropriate in a given situation, using the application. By clicking on any of the three buttons, more buttons would pop up, reflecting the next segment or activity. Each button displayed a label to identify the activity and was connected with the robot to play gestures, emotions, and speech depending on the activity. Instructors and educators provided feedback on the session workflow and on the strategies, once they were implemented. These strategies were then grouped into four categories based on the off-task behaviours that the strategy could potentially address (see Table 3.3).

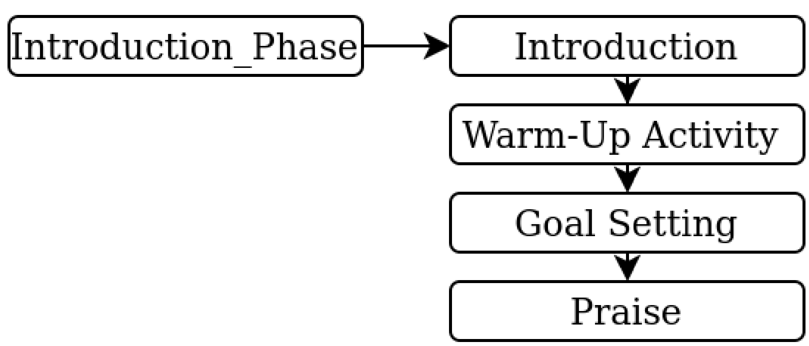



Figure 3.1: The steps of Introduction phase on the application.

[1]In the existing program, students work one-to-one with a qualified instructor on an ongoing basis to improve student independence, confidence, and academic success.

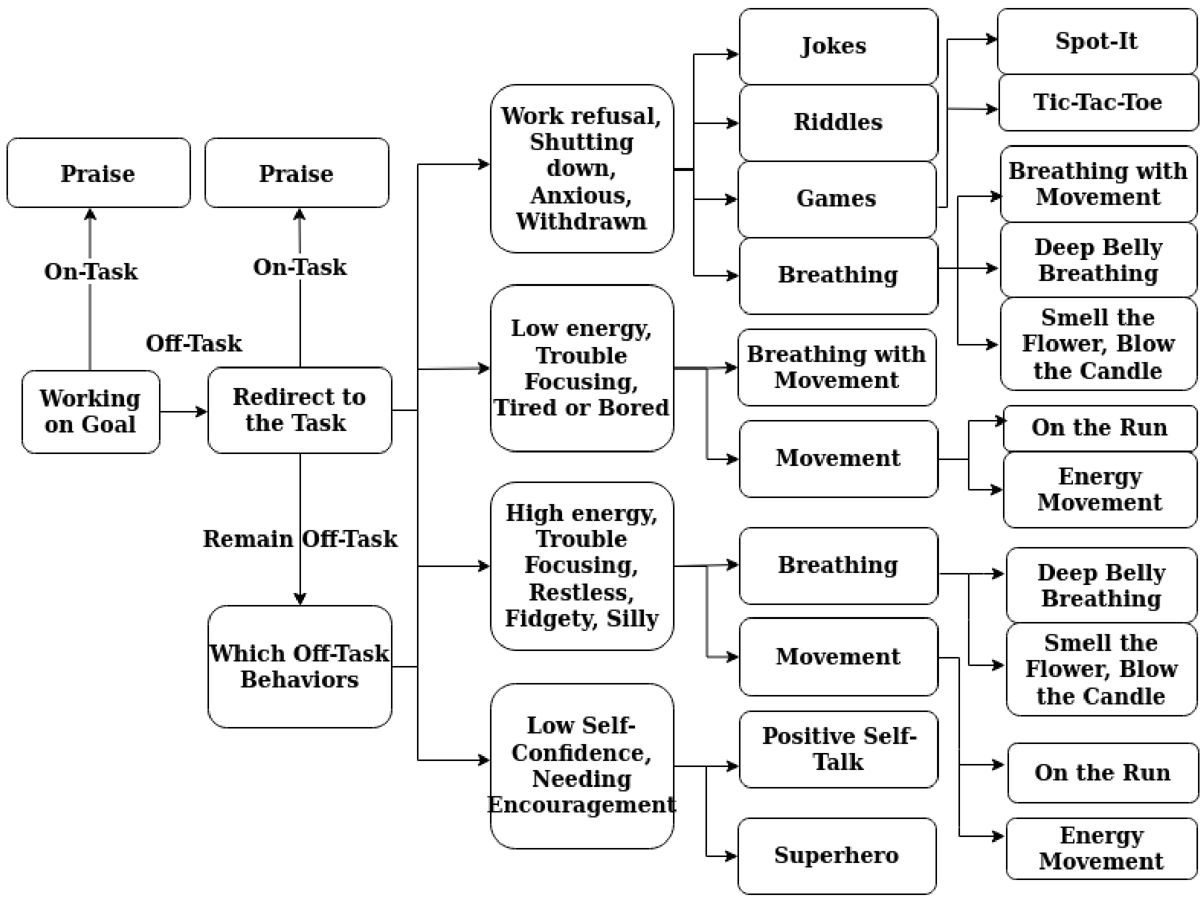



Figure 3.2: The steps of working on goal on the application. The instructors decided when to press the buttons and activate the robot's functionalities.

## 3.3 System Architecture

Fig. 3.4 (right) shows the architecture of the system. To connect the two tablets and the robot, we used Flask[2] a python web framework, to create web applications, and ROS (Robot Operating System) [101]. The QT robot[3] contains two computers that are internally connected with LAN, one is the Raspberry Pi based computer, and the other is Intel NUC i5/i7 PC. The ROS environment was initialized on the first computer and was used to send

[2] https://flask.palletsprojects.com/en/2.0.x/
[3] https://luxai.com/

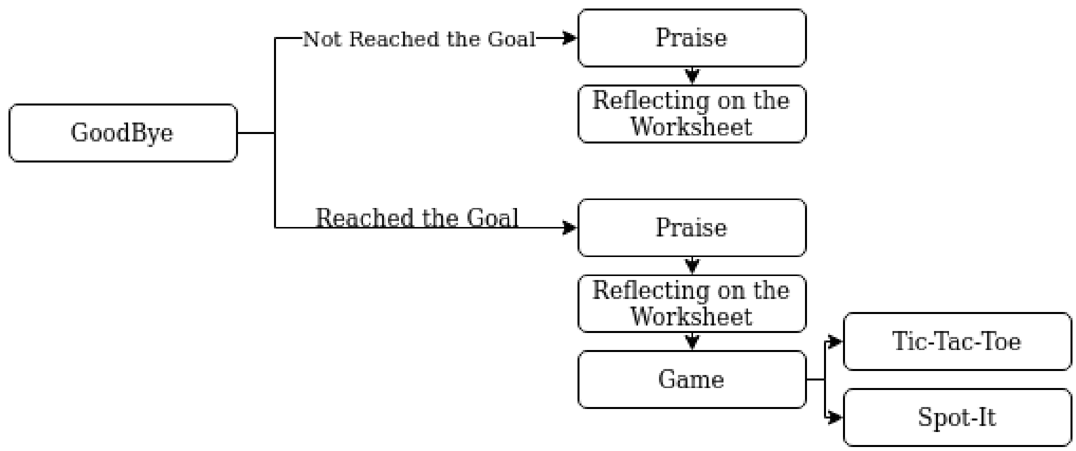



Figure 3.3: The steps of Goodbye phase on the application.

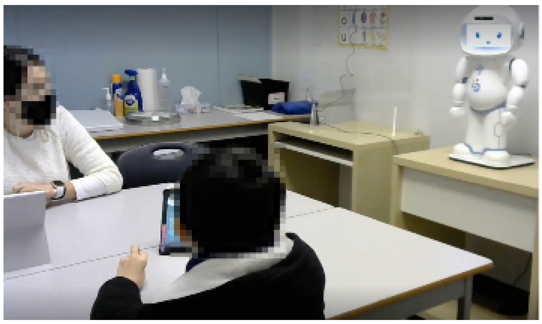
commands to the robot. The flask server was run on the second computer and was used to connect the two tablets and the robot. Flask provided an interface for the instructors' and students' tablets to connect to the robot and send commands to ROS. Further, ROS sends behavioural commands such as gestures, speech and emotional expressions to the robot.

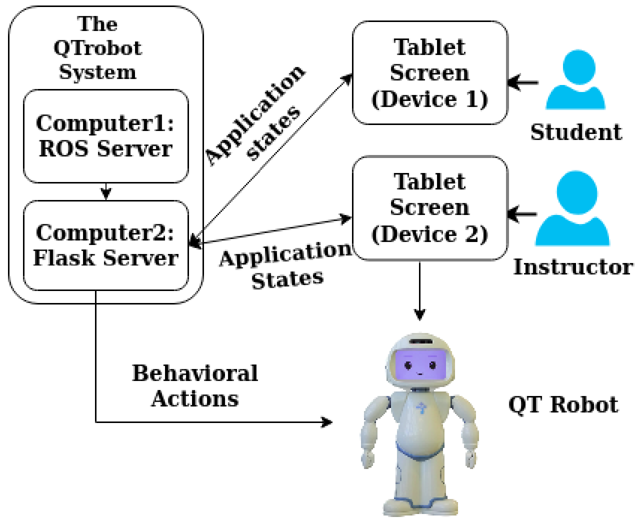
## 3.4 The Study

Our study was a within-participant design in which students participated in the IAU and RMI sessions. The scenario involved a setting in which an instructor provides a one-to-one personalized instruction to students.

## 3.5 Setting

The study took place within the non-profit educational organization in their teaching classrooms reserved for one-to-one instruction. The QT robot was located on a table along one classroom wall facing the student, approximately 1 to 2.5 metres away from the student and instructor. The instructor and students worked on a task at a table. No other instructors, staff, or students were in the room during instruction. A camera located next to the QT robot recorded the sessions. At the start of a session, a staff member set up the robot, the applications on the two tablets, and the camera.






[h]

Figure 3.4: Study set-up (left) and system architecture (right)

## 3.6 Materials

The materials in the study included two tablets, a video camera, worksheets, and the QT robot[4]. The QT robot is a commercially available, lightweight humanoid robot from LUXAI capable of various arm and head gestures and facial expressions.

The robot has 14 degrees of freedom, allowing it to move its head and arms and enabling it to make various gestures with an ROS interface for programming. The robot's face is a screen that can display facial expressions representing various emotions.

## 3.7 Participants

Four instructors and nine students participated in the study. The students were between 7 and 15 years old (See table 3.1 for a summary of participants). All participants were students enrolled at the organization. The organization enrols both students with diagnosed and suspected learning disabilities. The process for receiving a diagnosis can take years and is prohibitive to students presenting with significant foundational skill gaps and learning

[4]https://luxai.com/

needs not sufficiently supported in their schooling environment. Many of the students enrolled at the organization have multiple diagnoses, and participants recruited in this study also represent this. For the participants in this study, these diagnoses include but were not limited to ADHD, Autism, and developmental coordination disorder. The organization selected students who could potentially benefit from further support when facing difficult learning objectives. Instructors of the identified students were approached to gain their consent to participate in the study. Next, the parents/guardians of the students were asked for consent. Student assent was also sought before the first session of the research study. An ethical review of this study was completed through a community-based Research Ethics Office that has jurisdiction in the geographical location of the organization.

Table 3.1: A summary of participants sessions, and tasks

| Student ID | Age | NOS. of IAU Sessions | NOS. of RMI Sessions | Tasks |
|---|---|---|---|---|
| P14 | 9 | 2 | 6 | Reading, Writing, Spelling |
| N18 | 15 | 1 | 3 | Writing, Spelling |
| R18 | 11 | 1 | 3 | Reading, Math Riddles |
| P04 | 7 | 2 | 7 | Reading, Building Sentences |
| N03 | 10 | 1 | 3 | Reading, Writing |
| G13 | 7 | 1 | 3 | Reading, Writing |
| N17 | 8 | 1 | 7 | Word/Picture Sorting, Spelling |
| M13 | 13 | 2 | 6 | Picture Sorting, Spelling |
| Q20 | 8 | 2 | 6 | Reading, Writing |

* *NOS: Numbers of*

## 3.8 Procedure

The entire study took place over five weeks, with one-to-one sessions between instructors and students. The first week of the study was the IAU sessions, and the following four weeks involved the RMI sessions. During the IAU sessions, the instructor moderated and guided the student through the session, while the QT robot would do this during the RMI sessions. The instructors operated the robot using an application displayed on a tablet designed specifically for this purpose. The instructors had a short training session before the start of the experiment, to learn how the application interface worked. The instructor chose whether to use a redirection strategy and when and what strategy to use to allow for the following phases.

### 3.8.1 Introduction

This phase consisted of segments that included an introduction to the session, a warm-up activity (such as dance or a game); goal setting; and praise. The instructor sets a goal for students to work on. The tasks varied during sessions and from one student to another. The student reflected their mood and energy level using colours on their reflection worksheet. Table 3.6 displays a modified version of the Zones of Regulation framework displayed on a worksheet given to students. On their worksheet they had the same table as Table 3.6 with emotion images, above each column. Each colour correspond to a set of feelings and is categorized into a group [67]. Fig. 3.1 shows the steps of this part in the application.

**IAU sessions:** The instructor may start with a warm-up activity before they asked the student a set of goal-related questions and recorded the student's answers on the worksheet (see Table 3.2). At the end of this phase, the instructor praised the student for their efforts.

**RMI sessions:** RMI sessions follow the same as the IAU sessions, but were led by the robot instead. The robot introduced itself to the student by saying "I am going to help you in your session", and performed a warm-up activity. Then it asked the student to set a goal for the session with their instructor. In the end, the robot praised the student. Fig. 3.1 shows the steps of this part in the application.

### 3.8.2 Working on the goal

During this phase, the student, and the instructor began to work on the goal.

**IAU sessions:** As long as the student stayed on-task, the instructor would praise the student for their effort periodically. Whenever the student displayed off-task behaviours, the instructor would try to redirect the student to the task. If the student remained off-task, the instructor would engage the student with an RS. Each instructor in the study was provided with a list of strategies and how to use each of them. They chose the strategies depending on how the student felt and which off-task behaviours they displayed. After the student performed the strategy, they were able to re-engage the task. Fig. 3.2 shows the steps of this part in the application.

**RMI sessions:** The RMI sessions would follow the same procedure as the IAU sessions, except the QT robot would perform various actions. The robot would praise the student for staying on-task and redirect them back to the task. The robot would also facilitate the RS if the instructor chose to use one. The strategies that the robot could perform were the same as the list of strategies provided to the instructors in the IAU sessions.

### 3.8.3 Goodbye

This phase was where the student reflected on the goal they set with their instructor. The instructor also reflected their perceptions about the student's performance related to student's attention and commitment level, among other questions (please see Table 3.5).

**IAU Sessions:** The instructor would praise the student for their effort and asked a few follow-up questions about the session (see Table 3.4). The instructor recorded students' answers and their perceptions about the student's performance on the reflection worksheets. In the end, the student played a game with the instructor.

**RMI sessions:** The RMI sessions would follow the same procedure as the IAU sessions, except that the QT robot would provide the praise and ask the follow-up questions. The robot would also play the game with the student. Fig. 3.3 shows the steps of this part in the application.

### 3.8.4 Off-task behaviours and redirection strategies

Educators and researchers at the organization have identified a list of the most common off-task behaviours exhibited by students with LD at their centre. The identified off-task behaviours were further associated with the relevant redirection strategies. As shown in Table 3.3, the off-task behaviours were categorized into four parts. Different versions of each strategy were implemented to avoid repetitive interaction between the robot and the students that could negatively impact students' engagement. The purpose of using RS is to give the student a break from a task if the student begins to show signs of anxiety or frustration. Such strategies provide an opportunity for the student to reset their mindset before continuing with their task. In this study, we used the following strategies:

**Games:** Games were set up for the student to play with the robot in the RMI sessions and with the instructor in the IAU sessions. We prepared two tablets for this portion of the intervention. The instructor played on one tablet, or pretended that the robot was playing in the RMI sessions, and the student played on the other tablet. Initial study conversations with the instructors indicated the importance of designing the games in ways that were fun for students. They also asked to have more control over who won the games and when to play their turns, since some students required more time to play. We implemented two games for this pilot study, the Tic-Tac-Toe game fig. 3.5 [5], and the Matching game (Spot It). [6] The games' purpose was to keep students engaged. These two games had a competitive theme, but the QT robot gave feedback verbally during every turn, accompanied by appropriate gestures and affective expressions to encourage the student to keep playing. See fig. 3.6. Fig. 3.2 shows different parts of the application and the steps of every session.

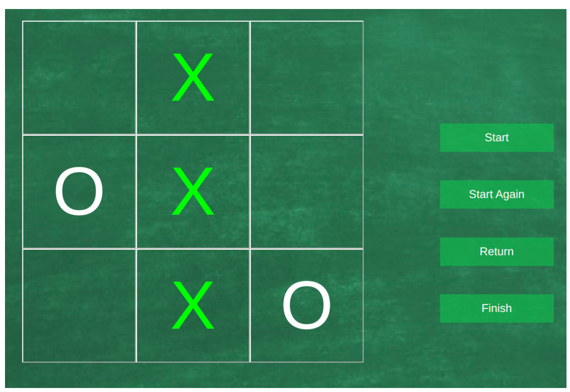



Figure 3.5: The Tic-Tac-Toe Game

**Humour and Riddles:** Humour and riddles were used to lighten the mood of the student and as a quick distraction from the task. We found some jokes for kids online and

[5] A game for two players to take turns to mark a grid table of three-by-three by 'X' and 'O's. The robot puts 'X' and the student puts 'O' marks. The first player to get 3 of their marks in a row (up, down, across, or diagonally) is the winner.

[6] A game for two players where each player is given a set of four pictures. There are four pictures each on the right, left and centre of the screen. The robot has to select a picture on the right, matching a picture shown in the centre of the screen. The student has to find the picture on the left that is matching a picture shown in the centre of the screen. The player who selects the matching picture first wins.

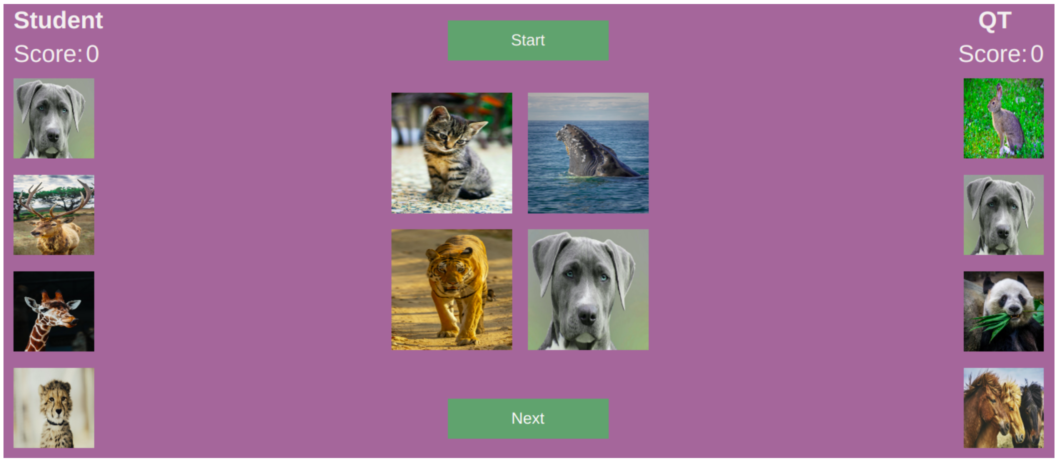



Figure 3.6: The Spot-It Game

implemented them into the robot's speech commands. Jokes and riddles were told by the robot in the RMI sessions and the instructor in the IAU sessions. For example, "Why are fish so smart? Because they live in schools! Haha! Haha!" [7], "Why are teddy bears never hungry? They are, always stuffed! Haha! Haha!" [8]

**Breathing Exercises:** Breathing exercises were implemented as part of the set of SR strategies as they can be used to reduce anxiety, help settle a restless student, and help promote focus [79]. Three breathing exercises were used in this study: 1) Breathing with Movements, 2) Deep Belly Breathing, 3) Smell the Flower, Blow the Candle. When the robot, or the instructor, performed one of these breathing exercises, they did so by gesturing using their hands, talking through the steps of the exercise and expressing emotions to guide the student through the exercise.

**Physical Movements:** Physical movement activities were selected as part of the set of SR strategies as they can be used to help settle a restless student or help engage a student that appears to be tired or has low energy [110]. Two physical movement activities were used in this study: 1) On the Run, and 2) Low Energy Movements. Similar to the breathing activities, the QT robot, or the instructor in the IAU sessions, would perform and guide the student through the exercise using arm gestures, speech and emotions.

**Positive Self-Talk:** Students often experience negative emotions when struggling with challenging tasks. To address this, educators used positive self-talk statements to

[7] https://www.goodhousekeeping.com/life/parenting/g28581033/best-jokes-for-kids/
[8] https://www.ezschool.com/Riddles/Riddle54Ans.html

reduce the negative emotions a student is experiencing. With these RS, the robot, or the instructor in the IAU sessions, would ask the student to repeat the positive self-talk statements (i.e. "I can do this".) The robot would also use gestures and, in the case of the Superhero Sequence, would ask the student to replicate them. The Superhero Sequence is a combination of positive self-talk statements and power poses (e.g. hands on hips).

Table 3.2: Questions on the worksheet for students

| Before Working on a Goal | After Working on a Goal |
|---|---|
| 1-What goal will you work on today? | 1-Have you reached your goal? |
| 2-How will you do it? | 2-What helped/didn't help you? |
| 3-How will you know you reached your goal? | 3-What will you try next time? |

## 3.9 Data Collection and Analysis

Study data comprised of video recordings of student sessions during both the IAU and RMI conditions and student reflection worksheets containing session feedback from instructors and students. The worksheets provided us with information on how students and instructors perceived the session, what strategies were used, and whether the goal was completed. In the RMI sessions, instructors were asked several additional questions related to goal setting, RS and the robot. See Table 3.4 for more details. Video recordings of the portion of the session where students worked towards their identified goal underwent a numerical analysis to track and record off-task behaviours by students. The first goal the student and instructor set for the session was analyzed using the momentary time sampling method. The students' working time on the goal was divided into one-minute intervals [94]. Prior to full analysis of the data, three of the organization-based researchers conducted the process of Investigator Triangulation, a process commonly used in educational research, to ensure rigorous analysis of the data. For this study, Investigator Triangulation was completed through each of the three investigators independently analyzing three of the video recordings and comparing their completion of the momentary time sampling method for each of the videos. The investigators compared their results and analysis of the three selected sessions together and found a high level of fidelity in the analysis of the videos. Where there were discrepancies in the analysis of data, the discrepancy was discussed, and a protocol was developed to clarify the analysis protocol and complete the triangulation process. The full analysis of all videos was then completed by two of the organization-based researchers

Table 3.3: Type of off-task behaviours, each associated with RS

| Off-task Behaviours | Redirection Strategies |
|---|---|
| Work Refusal, Shutting Down, Anxious, Withdraw | Jokes, Games, Riddles, Breathing (Breathing with Movement, Deep Belly Breathing, Smell Flower Blow the Candle) |
| Low energy, Trouble Focusing, Tired or Bored | Movement (On the Run, Energy Movement), Breathing with Movement |
| High energy, Trouble Focusing, Restless, Fidgety, Silly | Breathing (Deep Belly Breathing, Smell Flower Blow the Candle), Movement (On the Run, Energy Movement) |
| Low Self-Confidence, Needing Encouragement | Positive Self-Talk, Superhero |

Table 3.4: Questions on the Worksheet for instructors (Post-Goal)

| |
|---|
| 1-Did you set a challenging, yet achievable goal with your student? |
| 2-Which off-task behaviour(s) did you observe in the session? |
| 3-Which redirection strategies did you try and was it appropriate for your student (if applicable)? |
| 4-Did you follow the procedure details as outlined? If not,when/why did you go "off script"? |
| 5-Is there any other feedback you could provide that would be helpful to know for future sessions? |
| 6-Did the QT robot meet the objectives for the sessions(only to be answered during the RMI phase)? yes/No, Details: |

Table 3.5: Table of attention and commitment, levels of students filled out by instructors after working on goal [96]

| Attention and Commitment Level |
|---|
| Engagement: High Attention, High Commitment |
| Strategic Compliance: High Attention, Low Commitment |
| Ritual Compliance: Low Attention, Low Commitment |
| Retreatism: No Attention, No Commitment |
| Rebellion: Diverted Attention, No Commitment |

Table 3.6: Zones of Regulation, associating feelings with colours, filled out before and after working on goal, adapted from an original table [67]

| Blue | Green | Yellow | Red |
|---|---|---|---|
| Sad | Happy | Frustrated | Mad/ Angry |
| Sick | Calm | Worried | Terrified |
| Tired | Fleeing Okay | Silly/ Wiggly | Yelling/ Hitting |
| Bored | Focused | Excited | Elated |
| Moving Slowly | Ready to Learn | Loss of some Control | Out of Control |

to identify off-task behaviour and extract critical features of the session using the momentary time sampling method.

The analysis of videos began once the student began to work on the identified session goal, and the analysis ended once the goal was reached or the instructor re-directed the student if the goal was not met. For the momentary time-sample, the annotator would watch the 10 seconds leading up to the start of the next 1-minute interval to determine whether the student was on-task, based on behaviours displayed. An on-task behaviour would be defined by the annotators based on the goal set for the session. For example, if the goal was to read and answer questions about a passage, on-tasks behaviours of the student would include, but not limited to, reading, receiving help to pronounce words, answer questions about the passage. An off-task behaviour would be anything not related to achieving the set goal, like refusing to read or students telling off-topic jokes. If an instructor used a redirection strategy with the student, momentary time sampling would stop until the instructor directed the student back to their learning goal. After the goal-setting time was analyzed, the percentage of on-task behaviours was calculated by dividing the total number of one-minute intervals when the students were on-task by the total number of one-minute intervals in the session. The percentage of on-task behaviours was calculated for the intervals before and after using the RS during a session.

## 3.10 Results

In this section, we present the major findings obtained from the analysis of the data with respect to our research questions. RQ1 investigates if the presence of the robot would support the on-task behaviours and learning goal completion of the students. The following results illustrate a trend toward the social robots' support in students' learning.

### 3.10.1 Students' percentage of on-task behaviours

Fig. 3.7 shows the percentage of on-task behaviours for each student per session. By comparing the percentage of on-task behaviours between the IAU and RMI sessions in Fig. 3.7, we can observe that for most of the students, the percentage of on-task behaviours in the RMI sessions was higher than in the IAU sessions. However, there are a few exceptions that are further detailed in the Discussion section.

### 3.10.2 Goal Completion

RMI sessions had a greater goal completion rate than the IAU sessions. On average, students completed their goals in 91% of the session in the RMI phase and 77% of the IAU sessions.

### 3.10.3 Students' and instructors' perceptions of the QT robot

As shown in Table 3.8, we observed that seven out of nine students mentioned in the worksheets that the QT robot helped them. Six students mentioned that the RS moderated by the QT robot helped them in more than one session. Three students mentioned that they would ask the QT robot for help in future sessions. In the RMI phase, we asked the instructors to reflect after every session "if the QT robot has met the objectives of the session", and in more than 80% of the sessions, they replied 'yes'. RQ2 explores the impact of redirection strategies provided by the robot on redirecting students' focus back

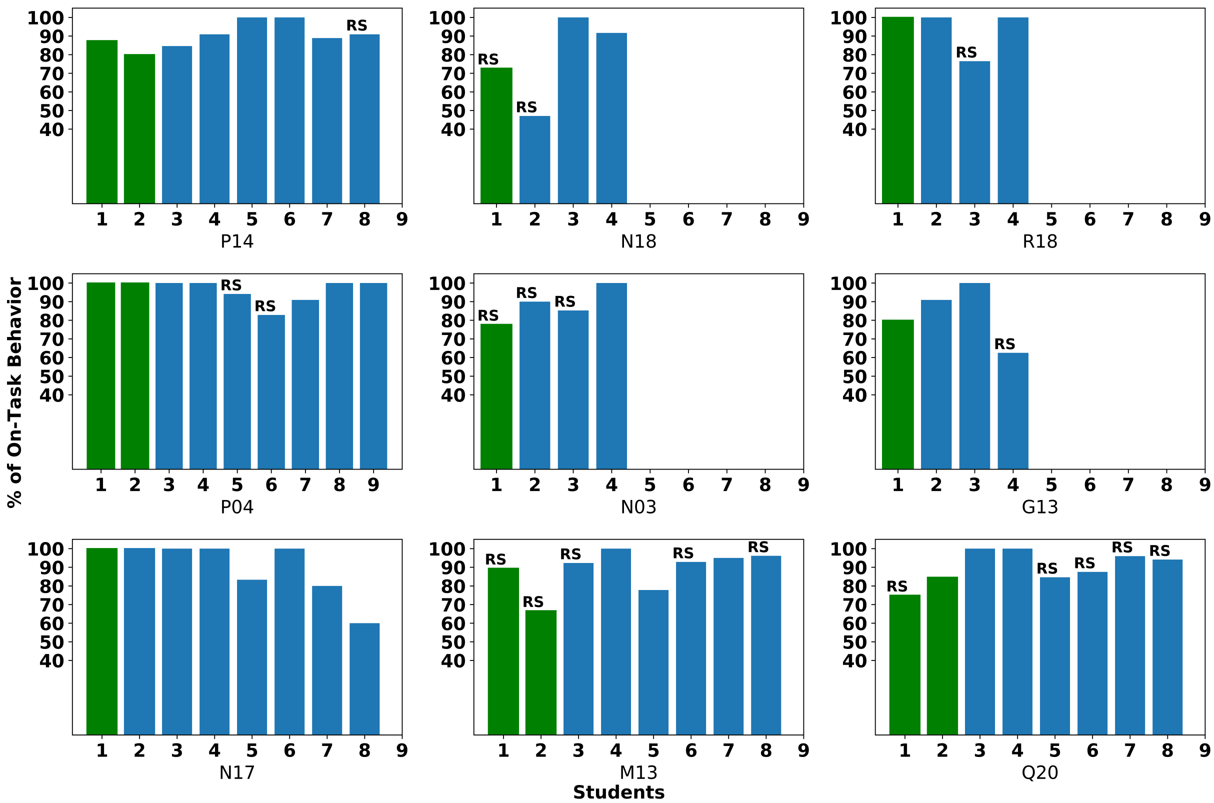



Figure 3.7: The percentage of On-Task Behaviours in the IAU (Green) and RMI sessions (Blue) for all students. The x-axis represents the session number for each student, and the y-axis represents the on-task percentage. 'RS' represents redirection strategy. Each graph represents a student and each bar in the graph represents a session of that student.

on a challenging task. The following results suggest the RS exhibited by the robot helped the students.

### 3.10.4 Impact of RS during RMI Sessions

To investigate if the RS moderated by the robot was effective, we measured the percentage of on-task behaviours before and after employing the redirection strategy, see Fig. 3.8. The frequency of SR being used in IUA sessions (38%) was about the same as the RMI sessions (34%).

### 3.10.5 Types of off-task behaviours exhibited by the students and most preferred strategies

Table 3.7 summarizes the types of off-task behaviours demonstrated by students and RS used during sessions. The strategies preferred by students were jokes, praise, movements and breathing exercises. Among them, jokes were the most commonly used, and students' feedback indicated that they liked the jokes.

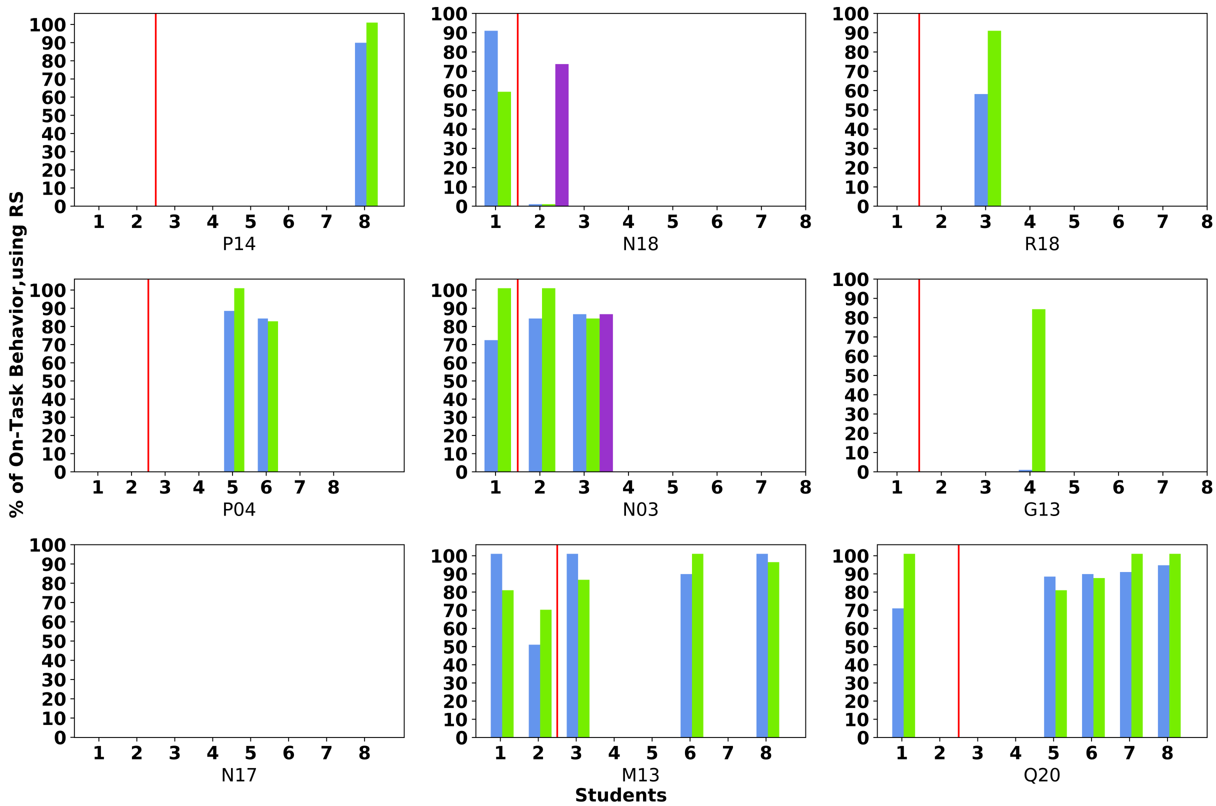



Figure 3.8: The on-task percentage, before and after using RS. The blue bar, indicates the on-task percentage before using the strategies, the green bar indicates the on-task percentage after using the first strategy, and the purple bar indicates the on-task percentage after using the third strategy. The red line separates the IAU and RMI sessions. If the student did not use the RS in a session, we did not plot any bars (see participant N17).

Table 3.7: Students' Off-task Behaviours Observed and RS Used during the RMI

| Students | Age | Off-task Behaviours | Strategies |
|---|---|---|---|
| P14 | 9 | Shut down | Jokes, Riddles, Breathing Exercises |
| N18 | 15 | Off-topic Talking | Jokes, Games |
| R18 | 11 | Got Stuck on Ideas | Deep Belly Breathing |
| P04 | 7 | Poor Posture, Tiredness | Breathing with Movements, Deep Belly Breathing |
| N03 | 10 | Chatting | Belly Breathing, Breathing with Movement, Jokes, Superhero |
| G13 | 7 | Shut Down | Jokes |
| N17 | 8 | Tiredness | |
| M13 | 13 | Off Topic Questions, Commenting on the QT robot's speech | Jokes, Energy Movement |
| Q20 | 8 | Frustration, Shut Down, Low Energy | Jokes, Positive Self-Talk, Low Energy Movement, Superhero, Praise |

### 3.10.6 Mood, Energy, Attention, and Commitment Level

We did not observe any significant difference between the moods and energy levels recorded at the beginning and the end of the sessions for both IAU and RMI. As the session often takes place after school and focus on challenging areas for that student, it is not unexpected that moods and energy levels do not change over a 50-minute session, even with a social robot. The subjective nature of these questions may also impact the students' responses, as they might have felt uncomfortable reflecting on their psychological and emotional states. Similarly, the instructor's recorded students' attention and commitment level did not change for most of the students before and after the session.

Table 3.8: Students'feedback about the QT robot (Post-Session)

| Students | Student's Feedback | Instructor's Feedback |
|---|---|---|
| P14 | The QT robot helped by praising("You did a good job today.", "Great Effort")! | The robot's involvement and praise helped the student feel proud and positive,and encouraged him to finish. |
| R18 | The robot's strategy helped. Asked the QT robot for help and more strategies. | The QT robot worked well and assisted in all steps. |
| P04 | Enjoyed the breathing exercise | The robot strategies seemed helpful, had a bit more energy. |
| N03 | The robot's strategies helped.I enjoyed hearing from the robot and wanted to explore more strategies.. | |
| N17 | The QT robot helped. | |
| M13 | Breathing, movement break and jokes helped. The QT robot motivated me. | The student enjoyed the breathing activity and asked Questions about the robot. |
| Q20 | The QT robot's jokes and movement breaks helped. | The student was incredibly focused. Jokes made them happier. Positive Self-Talk acted like a mood boost for them to finish the task. |

## 3.11 Discussion

The pilot study was specifically designed as a field study to explore the feasibility and value of using a social robot in an existing educational program for students with LD working with a specialized LD instructor. Because the study worked within the existing 'real world setting', systematic data collection was hampered by all the 'real world' challenges that students and educational organizations faced during COVID-19, such as scheduling challenges and lesson disruption due to sickness, and general family scheduling challenges. However, the goal of the study was to explore the intervention in relation to these 'real world' challenges, and thus the study's results and discussion focus on what we learned in relation to a 'real world' implementation.

Overall, the employment of a social robot seems to benefit students with their learning goals. In total, we had 44 RMI sessions. As shown in Fig. 3, the on-task behaviours for most of the students in most of the RMI sessions were more than 80%. Also, students completed their goals in 91% of the sessions without any drop-out. In some cases, these percentages were even further improved in the sessions. In addition, for most of the students, this percentage did not drop significantly by the end of their last RMI session, specifically, considering their diverse and serious learning conditions. We believe the repetitions in the RMI phase might have reduced the novelty effect of the robot on children. Moreover, the students' and instructors' feedback further supports the employment of the social robot.

The instructors at the educational organization had general experience working with technology (e.g., using computers, phones, etc.). They did not have technical expertise working with complex and sophisticated technologies such as robots in their one-to-one sessions. Each instructor had gone through the study protocol and had a one-to-one demonstration with one of the researchers to teach how to navigate the tablet app before conducting an RMI session. Additional technical support was given through the study when requested. With this minimal training, the instructors were able to use the social robot in the 44 sessions effectively.

## 3.12 Limitations and future work

As we wanted to explore the impact of a social robot on students' learning, due to the small sample size, we chose the within-participant design and employed the RMI sessions after the IAU session to slowly increase the complexity of the instruction medium as the students did not have prior experience with social robots. Most of the limitations related to the design of this study relate to its nature as an in situ study incorporated into an already existing program. As such, certain parameters which can be more easily controlled in a lab setting, such as the number of sessions and curricula/learning goals, were fixed. For example, instructors determined whether or not a redirection strategy was needed, and there was variance in whether a behaviour would warrant a redirection strategy and when the instructor would use another instructional technique such as a verbal reminder. However, off-task behaviour was recorded regardless of the instructor's technique, so we were still able to effectively measure the intervention's impact on off-task behaviour, the key goal of the study. As instructors had many responsibilities during a session, such as completing worksheets and controlling the robot, in addition to their general duties in supporting and scaffolding the learning of students, there were occasions where worksheets were incomplete. There were also a few sessions where the video recording equipment failed, so the sessions could not be included in the analysis. Learning from these limitations, we aim to improve our systems and protocols for a future study with the following changes: (1) to reduce the challenge of handling two tablets, we plan to remove one tablet by automating the games to lower the responsibility put on the instructors. (2) we plan to develop more collaborative games with additional themes and complexity levels to provide greater variety. (3) we also plan to change the study design to control for more conclusive results by addressing the identified limitations of this study: a) equal number of IAU and RMI sessions for each student; b) higher number of participants and sessions per participant; c) narrower age range of participants and common area of learning challenge; d) use of a between-participant design approach.

# Chapter 4

# Study 2: User Evaluation of Social Robots as a Tool in One-to-one Instructional Settings for Students with Learning Disabilities

This work is an extension of an in-situ pilot study, conducted to explore the integration of a social robot as an assistive tool for instructors, providing redirection strategies in a one-to-one instruction setting with children with LD.
The results of the pilot study indicated that the intervention supported students in staying on-task, however, there were limitations related to the study design, such as the technological complexity of the instructional protocol, and the absence of a control group.
Building from this work, the current study had an expanded scope that aimed to investigate how students with LD are impacted by a social robot as an instructional tool. We assessed the acceptance of the robot in one-to-one lessons as part of an in-situ study. Different from the pilot study, students were assigned to either a control or intervention condition.

## 4.1 Research Questions

The study poses the following research questions:
RQ1: What is the level of technology acceptance the robot achieves with both students and instructors?

RQ2: How does the use of a robot influence the engagement and off-task behaviours over the multiple sessions?

## 4.2 Participants

Sixteen students between 7 and 12-years old (mean= 9.6, std= 1.25) with a suspected or diagnosed LD participated in the study (See table 4.1). Five certified instructors (holding either a bachelors, master's degree or a teaching certificate) participated in this study (mean= 27.4, std= 1.74) (Table 4.3). Participants were existing LDS students who received one-to-one instruction with the participating instructor. The students struggled with reading tasks, and it was hoped that they could benefit from an assistive robot. The students were randomly assigned to one of the two conditions. Eight students participated in the *control condition*, where seven students had five sessions, and one student had six sessions. Eight students were assigned to the *intervention condition* (robot-mediated instruction); two of those students had six sessions, and five had seven sessions. One student was withdrawn after the first session in the intervention condition, since they were uncomfortable having the robot in their lesson (see table 4.2). The variance in the number of sessions by the students was due to missed sessions. While some students attended LDS twice a week and could make up missed sessions, some students were unable to do so as they only attended once a week. All instructors participated in both conditions, and none had used social robots previously. All instructors went through a training session and were demonstrated how the interface worked. Three instructors had two students participating in the study, and two instructors had one student participating.

## 4.3 Material

We used the same robot, QT, as in Study 1. It can perform gestures using its head and hands, accompanied by speech and facial expressions, and seems very suitable to use with children with LD. To interact with the robot, we developed a web application interface for instructors to operate the robot during the intervention sessions. The app consisted of the protocol instructors followed during the session, displayed as buttons. Examples of elements of the protocol are warm-up activities, games, and breathing exercises. The application was loaded onto a tablet, which the instructor used to control the robot to lead an activity or play a game with the student (as a part of the session).
In addition, we developed a reflection worksheet for instructors and students to reflect on

the academic goal of the session, including its difficulty level, and to state if the goal was reached during the session or not. Instructors also reported students off-task behaviours, engagement and the redirection strategies used on the worksheet. Additionally, students were asked to take part in a paper-based visual survey about their experience with the robot three times during the study, to gauge whether and how their opinions of the QT robot changed over the duration of the intervention period. This survey, that was developed according to the context of the research, included questions regarding the robot's friendliness, intelligence, and the student's enjoyment (Table 4.4). In order to evaluate the instructors' acceptance of the robot in their lessons, we created an online survey, on Qualtrics using the Technology Acceptance Model (TAM) [44, 31, 115, 116] consisting of the following categories: a) Perceived usefulness; b) Ease of use; c) Intention to use the robot (their willingness toward using it); d) Attitude toward using the robot (if they see any value in using it), e) Enjoyment, and f) Process of using the robot, on a 5 point Likert scale. In addition, we asked questions to rate instructors' interest in 'Affinity for Technology Interaction' (ATI) [40] on a 6-point Likert scale. Note, the TAM model was chosen since, while not as complex as other user acceptance models that are reported in the literature (e.g. UTAUT, [25]), was deemed most suitable for this in-situ study in order to answer our research questions without putting too much effort onto our participants. TAM has also been used successfully in a recently published in-situ study with children with ASD [103].

## 4.4 Procedure

This study was conducted after the pilot study, mentioned above, in which we investigated how the QT robot can influence the off-task behaviours of students with learning disabilities while working on a task. In this follow-up study, using a between-participant design involving a control and an intervention condition, we focused on designing a more structured session based on the lessons learned from the pilot study. Besides, we were interested in instructor's perception toward using the robot, in addition to students perception, and performance of the students in the lessons.
Students were randomly assigned to one of the two conditions. In order to provide an opportunity to interact with the robot to all the students, the control group later participated in the intervention condition after this study. In the intervention condition, the student only interacted with the instructor during a one-to-one instructional session, and in the intervention condition, the student interacted with the instructor and the QT Robot. During the intervention condition, the QT robot (controlled by the instructor) took over the

instructor role and lead the student through the session introduction, goal setting process, and provided self-regulation strategies if necessary. Students took part in the study once a week as part of their regular sessions with their instructor. Some students had more lessons in a week at LDS, but all participated weekly in our study. The instructor and the student worked on a reading task that was challenging but achievable for the student. Both conditions employed the following phases:

### 4.4.1 Introduction phase

**Control condition:** The instructor introduced the session, and completed a warm-up activity with the student. Next, the student and instructor set a goal for the session and the student reflected on their mood and energy level on the reflection worksheet.
**Intervention condition:** The phase began with the QT robot introducing itself, and introducing the session. Then, the robot and the student did a warm-up activity together and the robot asked the student to set a goal. Note, while QT performed some activities and behaviours autonomously, they were controlled by the instructor through the application. Thus ensured that the instructor was in full control of the session.

### 4.4.2 Working on goal

**Control condition:** During the session, the instructor redirected the student back on task as needed. If the student remained off-task, the instructor used a redirection strategy (RS). If the student stayed on task, the instructor praised the student.
**Intervention condition:** Intervention sessions followed the similar procedure as the control condition, except that QT delivered the RS or praise.

### 4.4.3 Goodbye

**Control condition:** At the end of the session, the student reflected on their goal. Sessions finished with a game, regardless of goal completion. Once the session was completed, the instructor answered a few questions about how the session went and the student's engagement.
**Intervention condition:** Intervention sessions followed the similar procedure as the control condition, except that QT delivered and played a game with the student.
Students also responded to questions regarding their interaction with the QT robot three times during the study. The three *data collection points* occurred after the first, fourth,

and last session. Instructors completed a technology acceptance questionnaire twice during the study, after the first and last session. Tables 4.5, 4.6, 4.7, 4.8, 4.9, and 4.10 show questions asked.

Table 4.1: Students' Demographic

| Student ID | Student Age | Number of Sessions | Instructor ID |
|---|---|---|---|
| d22 | 9 | 6 | 1334042 |
| d29 | 12 | 7 | 1365184 |
| e26 | 9 | 7 | 1365184 |
| e30 | 11 | 7 | 1336548 |
| j36 | 8 | 1 | 1336548 |
| d37 | 9 | 7 | 1348670 |
| e34 | 11 | 7 | 1322791 |
| i31 | 8 | 6 | 1322791 |

Table 4.2: Instructors sessions

| Instructor ID | NO. Students | Total NO. Sessions | 2nd TAM Survey Given After |
|---|---|---|---|
| 1334042 | 1 | 6 | 6 |
| 1365184 | 2 | 14 | 7 |
| 1336548 | 2 | 8 | 7 |
| 1348670 | 1 | 7 | 7 |
| 1322791 | 2 | 13 | 7 |

Table 4.3: Instructors' Demographic

| Instructor | Gender | Age | Qualifications | EXPC. | EXPC for LD |
|---|---|---|---|---|---|
| 1334042 | Male | 24 | Bachelors degree | 4 years | 3 years |
| 1365184 | Female | 28 | Masters' Degree | 8 years | 4 years |
| 1336548 | Female | 28 | Masters' Degree | 8 years | 3 years |
| 1348670 | Female | 28 | Masters' Degree | 5 years | 3 months |
| 1322791 | Female | 29 | Teaching Certification | 7 years | 1 year |

EXPC:Teaching Experience
EXPC for LD:Teaching Experience for children with LD

Table 4.4: Students questionnaire

| |
|---|
| How much did you enjoy having the robot in your class? |
| How many stars would you give to the robot for its friendliness? (The more stars, the friendlier) |
| How many stars would you give the robot for its intelligence? (the more stars, the more intelligent) |
| Do you think the robot helped you during the session? |
| Would you like to have the robot in your future classes? |
| How often would you like to have the robot in your future classes? |
| I think for the robot in my class as a ….. |

Table 4.5: Interaction(s) with Technical Systems

| |
|---|
| I like to engage more and in greater detail with technical systems. |
| I like testing the functions of new technical systems. |
| I predominantly deal with technical systems because I have to. |
| When I have a new technical system in front of me, I try it out intensively. |
| I enjoy spending time becoming acquainted with a new technical system. |
| It is enough for me that a technical system works; I don't care how or why. |
| I try to understand exactly how a technical system works. |
| It is enough for me to know the basic functions of a technical system. |
| I try to make full use of the capabilities of a technical system. |

Table 4.6: Perceived Usefulness

| |
|---|
| Using the robot enables me to accomplish teaching tasks quickly with students. |
| Using the robot enhances my effectiveness in teaching the students. |
| Using the robot supports student engagement in the lesson. |
| Using the robot supports the student in staying on task. |
| Using the robot support students in completing their learning goal. |
| Using the robot makes it easier to teach students. |

## 4.5 Study Results

The results of this study are presented in order of the research questions. First, we discuss the technology acceptance results of the users. Next, we present results regarding the

Table 4.7: Ease of Use

| |
|---|
| Overall, I find the QT robot useful in my job. |
| I found it easy to learn how to use the robot. |
| I find it easy to control the robot through the tablet interface. |
| I found it easy to understand (instructions) how to operate the robot. |
| It is easy to become skilful at using the robot system (robot and tablet). |
| Overall, I find the robot system easy to use. |

Table 4.8: Intention to Use

| |
|---|
| I want to use the robot during my one-to-one instructional sessions. |
| I am willing to use the robot in my future sessions. |
| I want to use the robot frequently in my sessions. |

Table 4.9: Attitude toward Using

| |
|---|
| I think it is a valuable instructional tool to use the robot in sessions. |
| I think it is a trend to use robots in sessions. |

Table 4.10: Enjoyment

| |
|---|
| I find using the robot enjoyable. |
| I have fun using the robot. |
| I find interacting with my students enjoyable when the robot is present. |
| I find students enjoy interacting with the robot. |
| I find students enjoy learning when the robot is present. |

impact of a robot as a tool on students' engagement level and off-task behaviours by comparing the control and intervention conditions.

### 4.5.1 Instructors' Perceptions

#### 4.5.1.1 Open-ended questions

After the first and last session, we asked open-ended questions to the instructors regarding the usage of a robot and its potential benefits to students (see Table 4.12). Table 4.11

Table 4.11: Instructors' perceptions after the last session

| ID | Experience | Benefits for Instructors | Benefits for students |
|---|---|---|---|
| I1 | QT is effective as a reward system and my student enjoyed the interactive portions. | Helpful for getting the students to stay on track/focus and help take pressure off me to do this. | Helps give them a goal to work towards and be involved in fun and engaging activities. |
| I2 | Good, I like it. | More usable with younger students. | Motivation in younger students |
| I3 | QT is a fun addition to the classroom. Most students enjoy QT's presence. A distraction at times, but the more they meet it the less distracting it is. | Ability to set goals with the students in a fun, interactive way. Less pressure on the student. Praise on-task behaviours or take breaks with QT. | More motivated and less pressured by QT's presence. It changes student's moods positively. |
| I4 | I enjoyed using QT | The strategies led by QT are helpful. Students respond better when QT leads them than when I do. | The robot's novelty made students more engaged and allowed them to enjoy the session more. My student asked lots of questions about QT it was not in our sessions. QT seemed to make them more excited. |
| I5 | Good! Helpful for maintaining engagement | Diversity in lessons, engagement, motivation tool | Diverse breaks, motivation, engagement, discussion topic |

ID: Instructor ID

summarizes the experience of the instructors and the benefits of using a robot for them and the students.

Only two instructors responded to questions 5, 6, and 7. Regarding difficulties, one of them did not encounter any issues in any of the sessions. However, two instructors mentioned

Table 4.12: Open-ended questions

| |
|---|
| 1. *How was your experience in using the QT robot? |
| 2. Did you perceive any benefits for yourself in using the robot as an educational tool? |
| 3. Do you see any benefits for students in using the robot? |
| 4. Do you have any worries and concerns in using the robot as an educational tool? |
| 5. *Did you face any difficulties in using the robot? |
| 6. *Did you encounter any technical problems during the session with the robot? |
| 7. *Do you have any suggestions to improve the interaction of the robot during the session? |

* These questions were asked after the last session

issues with one of the games (Tic-tac-toe) in which the robot did not respond appropriately; one of them was able to address this issue by restarting the game. The other instructor mentioned that the app was sometimes slow and had to be refreshed. Related to their suggestions to improve the interaction, one of them mentioned that the students really enjoyed the gestures of the robot, however, if it had shown more gestures, the students would have been more engaged. The other instructor suggested increasing the speaking and game playing pace. The word 'goal' spoken by the robot had a strange pronunciation, which was also noticed by the students. Regarding worries and concerns, after the first session, 3 instructors had concerns related to the distraction due to the novelty effect of the robot. Additionally, sometimes the robot glitched during a game, and adjustments to the robot's program were made to reduce these issues. However, after the last interaction, only one instructor had concerns. The instructor described the concern as follows, "Sometimes the students are more concerned with QT than with the lesson. However, this has appeared to diminish over time as they become familiar with the robot."

#### 4.5.1.2 Affinity for Technology Interaction

Instructors reflected on their willingness to interact with technical systems on a six-point Likert scale, (1: Completely disagree, 6: Completely agree). The average score for this section was 3.97 after the first and 3.7 after the last interaction, which shows medium affinity for technology interaction.The scores of the third instructor dropped after the last interaction due to some glitchy behaviours of the robot in some sessions. However, the scores of other instructors did not change significantly. Table 4.5 shows the questions of this section in the questionnaire.

#### 4.5.1.3 Technology Acceptance Model(TAM)

Table 4.13 shows the result of the TAM questionnaire completed by instructors on a five-point Likert scale(1:Strongly disagree, 5:Strongly agree).

As shown in Table 4.13, regarding the 'Perceived usefulness' and 'Ease of use', when comparing the first and the last session, only the first instructor, gave lower scores to the robot's usefulness and ease of use while others perceived the robot to be more useful and easier to use after the last interaction. Similarly, concerning the 'Intention to use', the instructors reflected on their wish to use the robot in their current and future lessons. Except for one instructor, the others gave higher scores in using the robot. For 'Attitude toward using the robot', instructors' opinion had little change concerning the value of the robot in lessons, and the scores show general positive attitudes. Regarding enjoyment, three instructors enjoyed using the robot more after the first session compared to the last session, for the others, the scores did not change. In addition, we asked a question 'Process of using the robot (scale 1-5 (unpleasant to pleasant))', all the instructors provided the score 4 and there was no change in the scores between the first and the last session.

### 4.5.2 Students' Perceptions

We asked students in the intervention condition (seven students) to reflect on their perception of the robot three times during the study with regards to the following aspects:

#### 4.5.2.1 Enjoyment

We asked students to reflect on how much they enjoyed having the robot in class, on a 5 point scale (from "Awful" to "Fantastic"). At all three data collection points (the first, fourth, and last session), four students selected "Really good-Fantastic" and three students chose "Okay". None of them selected "Awful" or "Not very good" anytime.

#### 4.5.2.2 Friendliness

At all three data collection points, all seven students gave 4-5 stars (1 to 5 stars; the more stars, the friendlier) for the robot's friendliness on a scale from 1 to 5 stars.

#### 4.5.2.3 Intelligence

After the first session, 1 student gave “1-2”, 2 students gave “3” and 4 students gave “4” stars for the robot intelligence on a scale from 1 to 5. After the fourth session, 4 students gave “3-4” and three “4-5” stars. However, after the last session, most of the students had a very positive attitude; 6 students gave “4-5” stars, and only 1 gave “3” stars.

#### 4.5.2.4 Robot’s help

Students were asked if the robot helped them. After the first session, 2 students said “I don’t know”, 1 said “Maybe” and 4 said “Yes”. After the fourth session, these changed to 3 students selecting “Maybe” and 4 students “Yes”. After the last session, we got 1 “No”, 2 “maybe”’s and 4 “yes”s from the students.

#### 4.5.2.5 Use of a robot in the future and how often

Next, we asked students how often they wanted the robot in the class, in the first session, 1 student said “Never-Rarely”, and 1 “Sometimes”, and 3 “Often-Always”. After the fourth sessions, 6 students said “Sometimes”, and 1 “Often-Always”. After the last session, from those students who had not said “No” to having the robot in class, 1 student said “Sometimes” and 5 students said “Often-Always”.

#### 4.5.2.6 Perceived role of the robot

Students’ opinion about the role of the robot, is shown in figure 4.1. After the first session, most students perceived the robot as a Friend, the next choice was a Helper, while fewer students reported Classmate, Stranger, Teacher as the role of the robot. After the fourth session, more students tended to see the robot as the Helper and fewer students chose Friend. Interestingly, after the last session, a more equal distribution of the roles “Classmate”, “Teacher”, “Helper” and “None” emerged. The choice of the robot’s role as a “Friend” decreased strongly during the study.

### 4.5.3 Control vs. Intervention conditions

We compared the students’ reflections (completed at the beginning and at the end of every session) during the study. We measured the ratings for the sessions that the worksheets

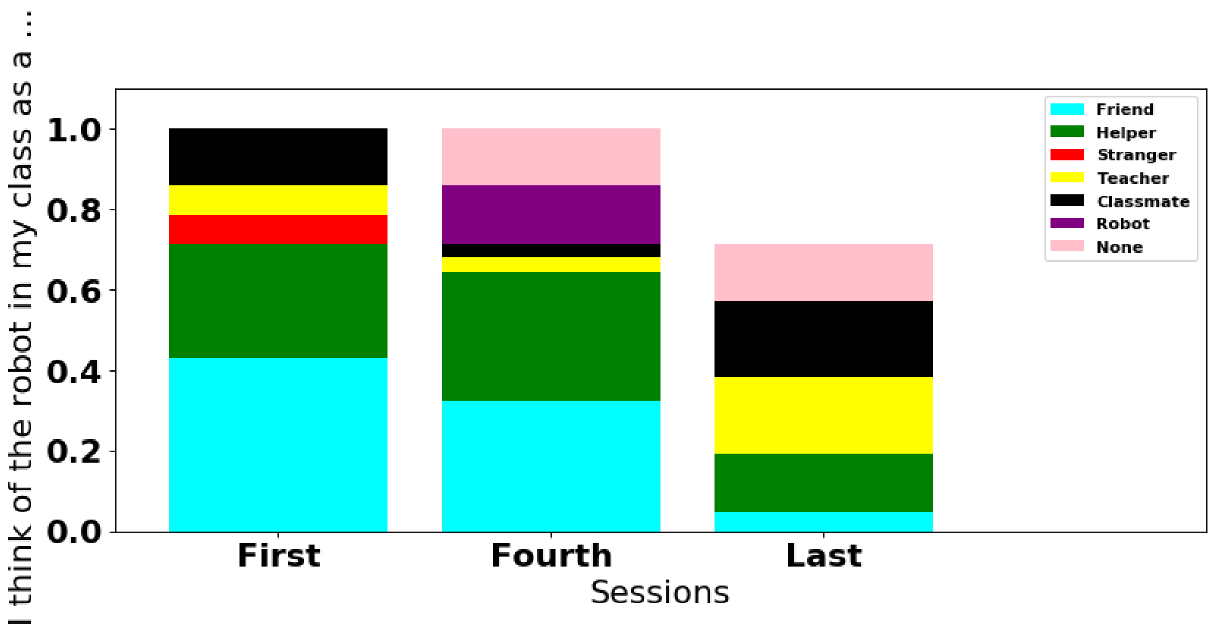



Figure 4.1: The role of the robot shown at the three data collection points

| I | Perceived Usefulness | | Ease of Use | | Intention to Use | | Attitude toward Using | | Enjoyment | |
|---|---|---|---|---|---|---|---|---|---|---|
| | FI | LI | FI | LI | FI | LI | FI | LI | FI | LI |
| I1 | 3.83 | 3.33 | 3.83 | 3.33 | 4 | 4.33 | 4 | 3.5 | 4 | 4 |
| I2 | 3.5 | 4 | 3.5 | 4 | 4.66 | 4 | 4 | 4 | 4.6 | 4 |
| I3 | 3.33 | 3.66 | 3.33 | 3.66 | 4.33 | 4.33 | 4.5 | 3.5 | 4.6 | 4.6 |
| I4 | 3.5 | 4.17 | 3.5 | 4.16 | 3.33 | 4.33 | 3 | 3.5 | 5 | 4.4 |
| I5 | 4 | 4.33 | 4 | 4.33 | 5 | 5 | 5 | 4.5 | 5 | 4 |

Table 4.13: The average score of each instructors for the different categories in the TAM questionnaire, (FI: First Interaction, LI: Last Interaction, I: Instructor ID)

were completed (blank answers were removed from the analysis).
While we could not find any statistically significant differences between the control and intervention conditions, we observed the following tendencies:
Students were more engaged and completed their goal with a higher rate in the intervention sessions (Control: 83.8%, Intervention: 91%, p-value: 0.65). Students in the intervention condition displayed fewer off-task behaviours than the control condition (Control:51%, Intervention: 35%, p-value: 0.15). The RS delivered by the robot was more successful than

delivered by instructors in the control condition (Control: 86%, Intervention: 95%, p-value: 0.61). Students were more engaged in the intervention condition ((Control : engaged: 50%, neutral: 29%, not engaged: 21% ; Intervention: engaged: 58%, neutral:34%, not engaged: 7%), p-value: 0.052)

## 4.6 Discussion

This study explored the use of a social robot in an already existing educational program, for students with LD, during one-to-one sessions with an instructor. Students were assigned to either a control or an intervention condition, and participated in multiple sessions.
Students in the intervention condition held a positive attitude toward the robot from the beginning of the study. While some students gave fewer 'stars' to the robot's friendliness at the end of the study, they still wanted to have the robot in their future lessons. Moreover, their engagement with the robot did not change during the study. However, their perceptions towards the role of the robot changed. Interestingly, the role of a friend diminished and four major roles, a classmate, teacher, helper, or none emerged by the end of the study.(see Figure 4.1).
Considering the instructor's responses to the open-ended questions, all the instructors enjoyed or found the intervention effective (See Table 1). The scores in the five dimensions of the TAM questionnaire during the study lied between 3.3 to 5, sho wing medium to good acceptance towards the tool. With a closer look, for the first, second, and fourth dimensions of TAM, the scores given by the first instructor lowered a bit after the last session. We believe that, this instructor had one student (who was mature) in the intervention group did not find the interaction with QT interesting. This experience likely negatively affected the instructor's opinion of the robot intervention. However, despite these lower scores, they mentioned that the robot was helpful for students to stay focused and more engaged. Overall, we did not see any significant difference in the enthusiasm of instructors to try technological devices between the beginning and end of the study.
Comparing the results of the control and intervention conditions, the findings imply that the robot has a positive effect on students. Due to the nature of the in-situ study, and the low number of participants, statistical tests failed to show significant differences between the two conditions. While we could not find any pattern in students' engagement and goal completion over the sessions in the intervention condition, the results indicate that students were generally more engaged with their task and could complete their task with a higher rate compared to the control condition.

## 4.7 Limitations and Future Work

Conducting an in-situ study during the COVID-19 pandemic posed severe restrictions on recruitment and data collection. For example, many families preferred having online lessons during that period, and some cancelled their lessons due to sickness or moved to online after the study began in-person. Although we have video recordings of the sessions, wearing masks during lessons made behavioural analysis challenging. The duration of the study was also impacted by breaks in the school calendar. Despite the limitations of this in-situ experiment, the study design allowed for an in-depth investigation of instructors' and students' perceptions of the robot that was used as part of their program.

In future work, it is recommended to 1) conduct a study with a larger group of both instructors and students during a longer-term study. 2) improve the application and the robot's skills, to be further adaptable to the needs of diverse students.

# Chapter 5

# Study 3: Play Dynamics in a Collaborative Game With a Robot as a Play-Mediator

The purpose of this experiment was to study play dynamics with the MyJay robot in a collaborative multi-player game with two different collaborative control conditions. We were interested in how participants adapt to each other during the game-play. We also wanted to see how the two different conditions influence participants' enjoyment and engagement. We designed two collaborative conditions, Shared and Fusion. In the Fusion condition, we particularly evaluated coordination among the players. In the Shared condition, we evaluated turn-taking. We hypothesized that the Fusion condition might promote better collaboration and lead to better engagement and enjoyment.

## 5.1 Research Questions

We aimed to answer the following specific research questions:
RQ1: Which collaborative robot control condition best promotes collaboration among the participants?
RQ2: Which robot control condition provides the best game experience in terms of enjoyment?
RQ3: Which strategies do participants employ to achieve collaboration?

## 5.2 Material and Methods

### 5.2.1 Study Overview

In this study, pairs of participants played together through a robot play-mediator, the MyJay robot, which is able to pick up and throw balls. The dimensions of the robot were $570 \times 330 \times 525$ mm. The robot was placed in a $2.85 \times 2.28m$ playpen with 10 foam balls (with a diameter of 101.6 mm) scattered across the floor. The robot operated within the pen, participants stood outside the pen. The game consisted in cleaning up the play pen, i.e. collecting the balls by picking them up with the robot and throwing them into a box, as fast as possible in two different collaborative control conditions. This study was approved by the University of Waterloo Human Research Ethics Board.

### 5.2.2 Experiment Design

Upon arrival in the experiment room, participants were equipped with heart-rate sensors. First, they performed baseline tasks to acquire baseline heart-rate data: read a text for 3 minutes to acquire resting heart-rate data; play a speed game on a tablet to acquire excited heart-rate data. (The participants played the fruit Ninja game, where they had to slice fruits and avoid bombs[1].) Afterwards, participants played individually with the robot for 3 minutes to acquire baseline joystick and heart-rate data. They were free to navigate, pick up and throw balls via the joystick. The joystick functionalities, as well as the robot capabilities, were explained to each participant beforehand. Participants then played together in the following two conditions:

**Shared condition:** One participant is in charge of navigation and the other one of handling the balls. Only the required functionalities are active on each joystick.
**Fusion condition:** Both participants can control every functionality of the robot but the robot answers commands if and only if both participants give the same commands at the same time, by averaging the two control commands. This condition was inspired by [45].

Before each condition, the rules were explained to the participants, i.e. what they could do with their joystick. The conditions were randomized for each pair. For each condition, we recorded joystick and heart-rate data, as well as videos. After each condition, the participants completed a questionnaire to assess their engagement and enjoyment. Finally,

[1] https://www.halfbrick.com/games/fruit-ninja

participants were thanked for their participation and escorted out of the study room. The study lasted between 45 minutes to an hour.

### 5.2.3 Participants

Twenty-four pairs of adult participants were recruited from the University of Waterloo. Participants were instructed to come with a friend. We did not have any age constraints, but only fully Covid-19 vaccinated students (undergraduate and graduate level) could take part in our study, due to our University guidelines at the time of the study. Participants received the information letter regarding the study beforehand and provided consent. They each received a 10C$ gift-card to thank them for their participation. Each participant were given an ID ranging from 0 to 47. Participants with an odd ID number were the first participant in the pair and in charge of navigation in the Shared condition, and participants with an even ID number, were the second participant in the pair and responsible for picking up and throwing balls.

### 5.2.4 Materials

#### 5.2.4.1 MyJay Robot

In this study, our custom robot MyJay[2] (See Fig. 5.1) was teleoperated by two XBox controllers. This robot was designed as a play-mediator robot with a zoomorphic appearance, aiming at facilitating play for children with upper limb challenges [74]. It can navigate in any direction and also has an intake, an elevator and a flywheel mechanism that allows it to pick up balls and shoot them.

#### 5.2.4.2 Questionnaire

Participants were asked to rate the following items with a 5-point Likert scale (ranging from 1 = strongly disagree to 5 = strongly agree), after each condition, as an online questionnaire on a tablet. The questionnaire contained selected items from [84] and [30]. Find the questionnaire items in table 5.1.

[2] https://github.com/hamzaMahdi/myjay-bot

Figure 5.1: Left: The MyJay robot; Right: the experimental setup with a pair of participants playing

#### 5.2.4.3 Heart rate sensor

We utilized the wearable PPG heart rate sensor, Polar H10 [3], for our heart rate data collection. The sensor can emit infrared (IR) light on the skin, and the optical sensor detects the reflection of the emitted IR light. The reflection is dependent on the blood flow through the IR focus, and since the blood flow is controlled by the heart, the heart rate measurement can therefore be inferred.

## 5.3 Analysis

### 5.3.1 Joystick analysis

We stored the values and frequency of commands sent to the joystick. This consists of the magnitude of movement along the X and Y axes, in a time series. We measured and compared the magnitude and frequency, among baseline and Fusion conditions. Since only the first player in each pair navigated the robot, and the other player picked up and threw

[3] https://www.polar.com/ca-en/sensors/h10-heart-rate-sensor

| |
|---|
| Q1: The activity was pleasurable to me. |
| Q2: I felt connected with others during the activity. |
| Q3: I liked interacting with others during the activity. |
| Q4: The activity was fun. |
| Q5: I am good at the activity. |
| Q6: I cooperated with others during the activity. |
| Q7: The activity made me feel good. |
| Q8: I felt frustrated while using MyJay. |
| Q9: I found MyJay confusing to use. |
| Q10: Using MyJay was challenging. |
| Q11: I lost track of what was going on outside the activity. |
| Q12: I felt very capable during the activity. |
| Q13: I felt challenged, but not over-challenged. |
| Q14: When I did the activity, I thought about nothing else. |
| Q15: During the activity, I was able to get better at doing it. |
| Q16: I felt challenged, but not under-challenged, during the activity. |
| Q17: I felt competent at performing the activity. |

Table 5.1: Questionnaire items

the balls, the use of the joystick in the Shared condition was limited and the frequency and magnitude of commands were not studied. Commands with a magnitude less than 0.1 (determined in prior tests), were considered noise and removed from our data series. Each joystick has two sticks, and participants could use any of them to send navigate the robot, if both sticks were triggered, we used the commands of the stick with a greater value.

#### 5.3.1.1 Frequency

We measured the average time, between any two commands sent to the robot in the Fusion and baseline conditions. We did not compute the frequency in the Shared condition, since the participant who was responsible for navigating the robot did not use the joystick all the time, the robot had to stop at some point to allow the other participant to shoot the ball. The other participant only used the joystick buttons for shooting and picking up balls. Therefore, the frequency would not give us a proper measure of how frequently the joystick was used due to task sharing.

#### 5.3.1.2 Magnitude

We analyzed the average of the magnitude of commands sent to the robot, during the Fusion condition and baseline. In the Shared condition, only one participant navigated the robot, and the second participant only used two buttons, to pick up and throw the ball, thus, calculating the magnitude of commands for only one participant in the pair was not comparable to other condition.
We defined the magnitude as any efforts to move the robot along the x (forward/ backward) and y (rotation) axis. The value in each direction varied between -1 to 1, showing the amount of force applied to press the stick.

### 5.3.2 Video Analysis

The videos were labelled with some behavioural events defined in Table 5.2, such as pointing, gesturing, giggling/laughing, both participants looking at each other, one participant looking at the other, looking at the experimenter, cheering, and talking. For each behavioural event, we counted the number of occurrences.
One of the researchers of this team work defined definitions for each behavioural event and annotated all the videos. Another researcher was trained on those definitions and annotated 10% of the videos. The inter-rater agreement was 86%.

### 5.3.3 Heart rate analysis

**Resting and Stimulated Levels:**
We designed two activities to obtain the resting and stimulated heart rates of each participant. For the resting heart rate, the participant read a calming short story for 3 minutes, and for the stimulated heart rate level, the participant plays fruit ninja [4].) for 3 minutes. We recorded their heart rate during these events to compute their average resting and stimulated heart rate levels. In addition, we also recorded each participant's heart rate during their first interaction with the robot as a backup data source for the stimulated heart rate calculation, if the resting state heart rate was greater than the average heart rate throughout playing the fruit ninja game (while we hoped for the fruit ninja game to provide an exciting stimulus, this might not have worked for all participants).

We discarded the first 30 seconds and the last 60 seconds in each data series to prevent

[4] they sliced fruits and avoid bombs to get score, https://www.halfbrick.com/games/fruit-ninja

| Code | Behaviour | Description |
|---|---|---|
| A1 | pointing | gesture specifying a direction, by extending the arm, hand, and index finger |
| A2 | gesturing | gesture relevant to the game, other than pointing |
| A3 | laughing | laughing/giggling |
| A4 | looking at each other | both participants look at each other at the same time |
| A5 | P0 looking at P1 | participant 0 of the pair looks at participant 1 |
| A6 | P1 looking at P0 | participant 1 of the pair looks at participant 0 |
| A7 | looking at experimenters | gaze directing towards the experimenters |
| A8 | cheering | shouting for joy / excited behaviour like hugging / high-fives |
| A9 | talking | estimation of sentences uttered between participants |

Table 5.2: Definitions used for the video annotations

heart rate elevation due to activity novelty and heart rate drop due to activity habituation. We then computed the time series average in the two activities to obtain the average resting and stimulated heart rate level for each participant (Defined them as "Resting Level" and "Stimulated Level").

Six out of 48 participants were removed from the data pool for heart rate analysis since their average resting heart rate was higher than their average stimulated heart rate. For 12 participants, we used the average heart rate recorded for the joystick baseline condition, as the stimulated measure, since it was greater than the average heart rate measured while playing the fruit ninja game.

**Fusion and Shared conditions:**
We then recorded heart rate data in the Fusion and Shared conditions, and we computed the 10-second moving average (MA) of each condition. We classified a moving average heart rate as an *Excited Interval* if the heart rate was greater than the Stimulated Level. Then, we divided the number of Excited Intervals by the total number of 10 seconds intervals in

each condition.

## 5.4 Results

### 5.4.1 Joystick: Frequency

The average number of commands sent to the robot was 27.4 per minute in the Fusion condition, while it was 52 in the baseline condition (in the baseline condition, each participant played individually and navigated the robot using one joystick and tested different functionalities of the robot, for three minutes). We observed that participants tended to use the joystick more frequently when they were playing individually than in the Fusion condition. This could be due to the fact that participants needed more time to synchronize their commands and cooperate to be able to jointly navigate the robot. We defined the number of commands sent to the joystick within one minute as the frequency and performed a paired t-test on the frequency of commands to support our hypothesis (there is a difference between the frequency of sending joystick commands between the Fusion and Shared condition). To have a vector with the same length as the baseline condition, in order to use a paired t-test, we used the frequency in the Fusion condition, for both participants. The result showed a significant difference ($p < 0.001$) in the frequency of joystick commands between the Fusion and baseline conditions.

### 5.4.2 Joystick: Magnitude

The results revealed that participants applied more force in the baselines than in the Fusion condition. The average magnitude of commands was 0.5 in the baseline, and it was 0.4 in the Fusion condition. A paired t-test supports our observations of a significant difference ($p < 0.01$) in the magnitude of the x- y joystick axis, between the Fusion and baseline conditions. We explain this by the fact that the two participants, in each pair, tried to cooperate together and synchronize the commands sent to the robot. In order to get more control, the intensity of the commands was reduced compared to the baseline condition when they were playing separately.

### 5.4.3 Fusion condition: Coordination

In the Fusion condition, we are interested in the coordination between participants. To see if the participants were coordinated, we checked the proportion of time when both

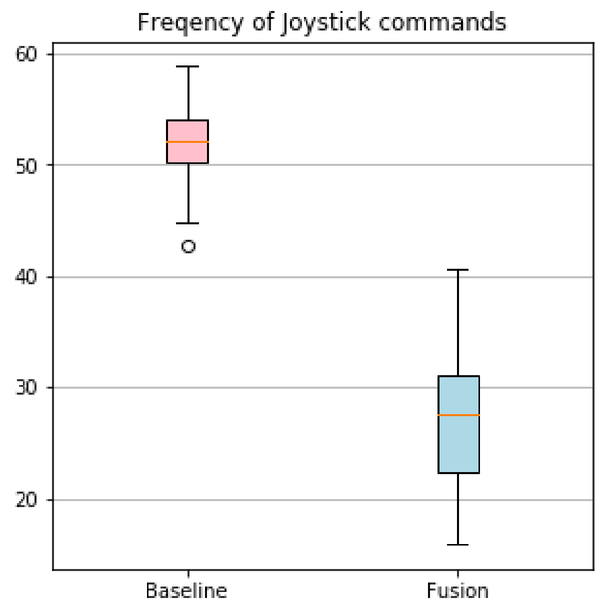



Figure 5.2: The average number of commands given in one minute

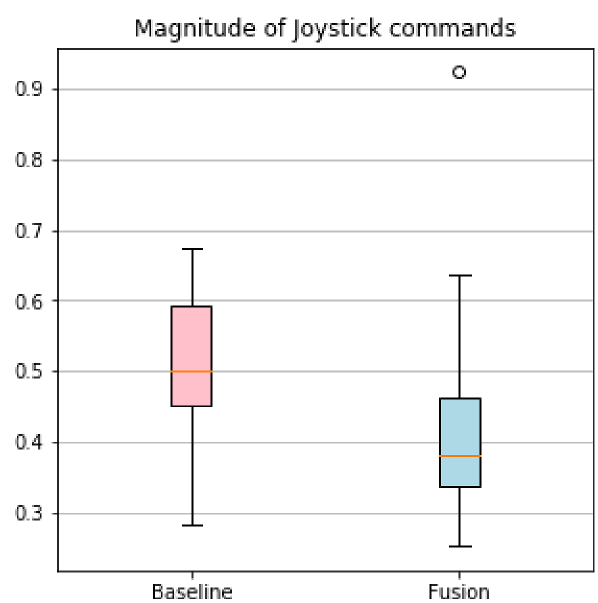



Figure 5.3: Participant's usage of Joystick during the Baseline and Fusion Condition

players activated the same joystick axis at the same time. First we define *overall coordination* as: $\sum(J1 == J2)/T_n$ where J1 and J2 are the joystick of the first and second player respectively and $T_n$ is the number of timesteps, (overall coordination values for Forward/Backward axis (FB): $0.64 \pm 0.07$, Left/Right axis (LR): $0.63 \pm 0.07$), this metric considers all the data and although it provides a good overview of how coordinated the participants were across the entire interaction, it can be biased if there was a lot of idle time. We therefore define *active coordination*, which only considers the data when at least one of the joysticks is active, as $\sum(J1 \text{ AND } J2)/\sum(J1 \text{ OR } J2)$ (FB:$0.36 \pm 0.06$, LR: $0.32 \pm 0.06$). See Figure 5.4 for results on overall and active coordination. We also calculated how often each joystick was active to detect play imbalance and if a player was just randomly giving commands (J1: $0.5 \pm 0.08$, J2: $0.39 \pm 0.13$) and the Pearson correlation coefficient (FB: $0.41 \pm 0.13$, LR: $0.27 \pm 0.14$). Figure 5.6 shows an example of windowed time lagged cross-correlation where the leader-follower relationship varies over time between both participants.

### 5.4.4 Shared condition: Turn-taking

In the Shared condition, we evaluate turn-taking. Specifically, we measure whether the players respected their assigned roles and if they were waiting for their turn to give commands.

*Overlap* is defined as $\sum(J1 \text{ AND } J2)/\sum(J2)$. Results show that participants did not always wait for their turn, as evidenced by $40 \pm 14\%$ of overlap on average, with a minimum of 13% and a maximum of 67%.

In 7 pairs, the person in charge of navigation was still pressing the button to try and shoot balls, even though it was made clear to them that the buttons were deactivated. In 19 pairs, the person in charge of the balls also tried to navigate the robot by moving the stick on the joystick.

### 5.4.5 Videos

Overall, the participant pairs communicated more with each other in the Fusion condition than in the Shared one. The video analysis revealed the different collaboration strategies that the participants adopted in the Fusion condition: in most cases, a leader emerged and gave most of the commands, usually by pointing and talking. In some pairs, the "leader" also placed their joystick in front of their partner, so that they could see and replicate the commands. For the Shared condition, participants mostly played independently. The

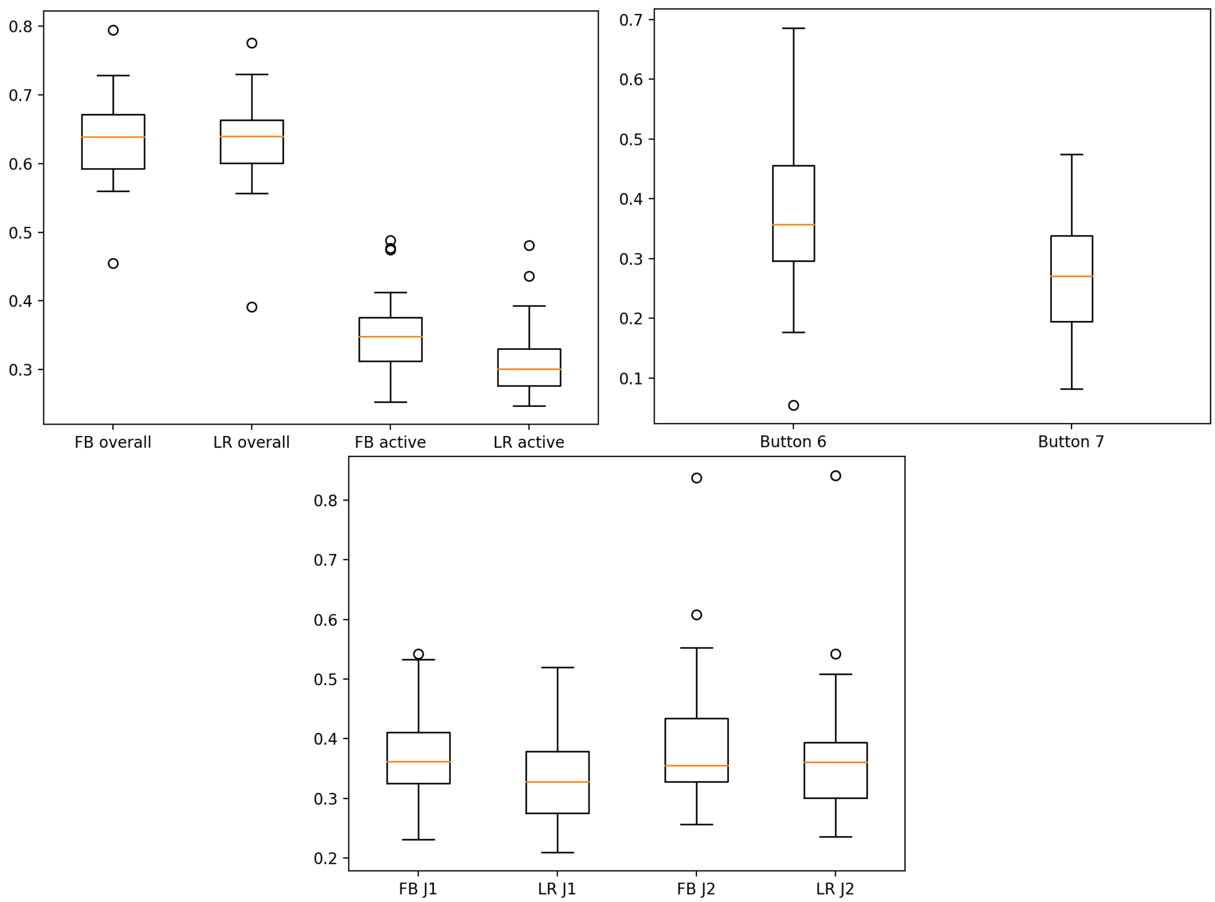



Figure 5.4: Top Left: Overall and active coordination for the joystick (FB: forward/backward axis of the joystick; LR: left/right axis of the joystick). Top Right: Active coordination for the buttons. Bottom: Percentage of time where each joystick is active during the interaction

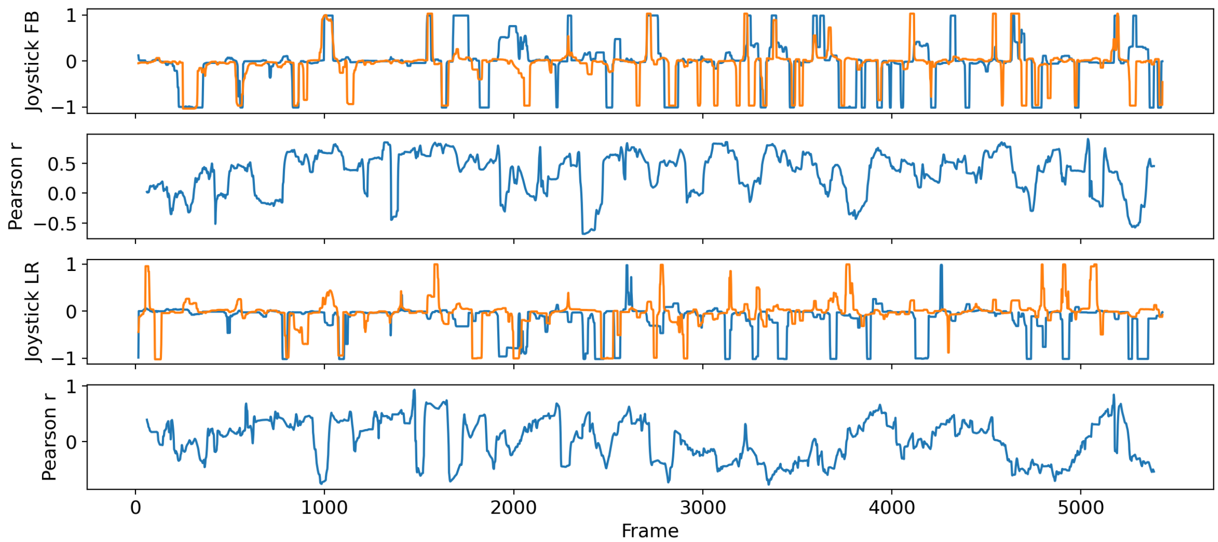



Figure 5.5: Example of joystick commands and correlation over a sliding window for pair 10.

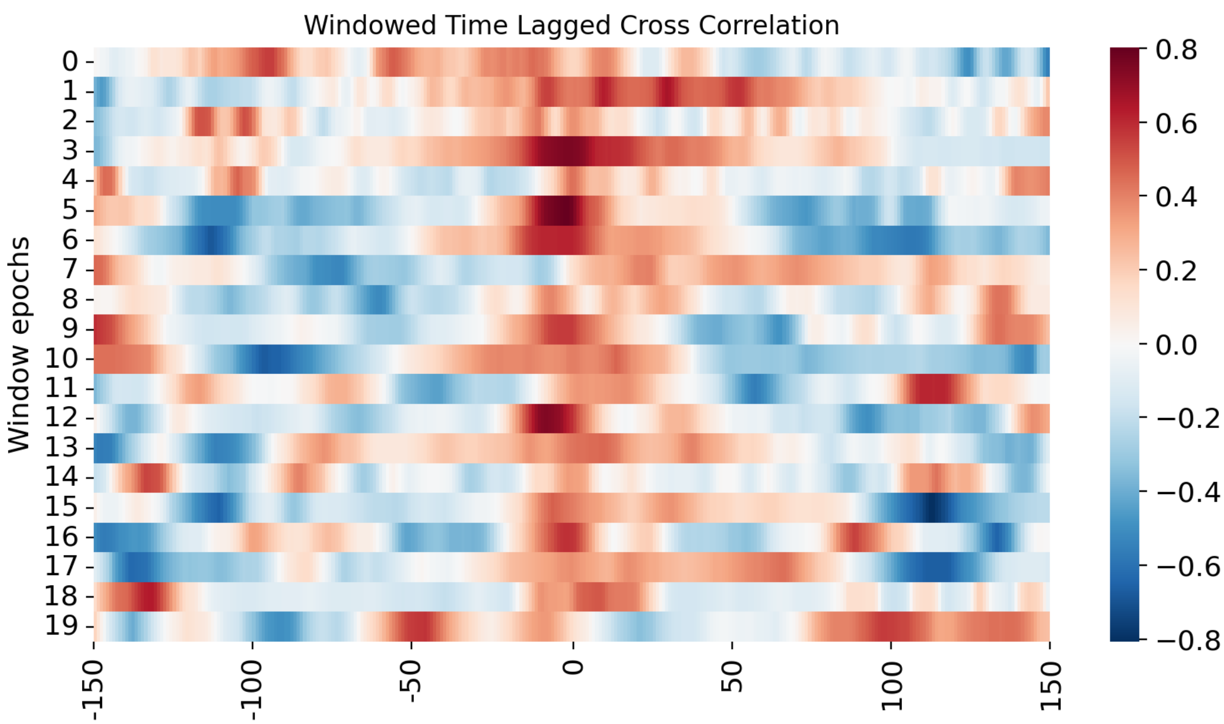



Figure 5.6: Example of windowed time lagged cross-correlation for the forward/backward direction for pair 10.

video annotations revealed that the participants performed more pointing gestures, giggled/laughed more, looked at each other more and talked a lot more in the Fusion condition (See Fig 5.7).
However, no correlation could be found between the video analysis (number of cooperative behaviours, amount of talking) and the coordination scores computed in section 5.1. We

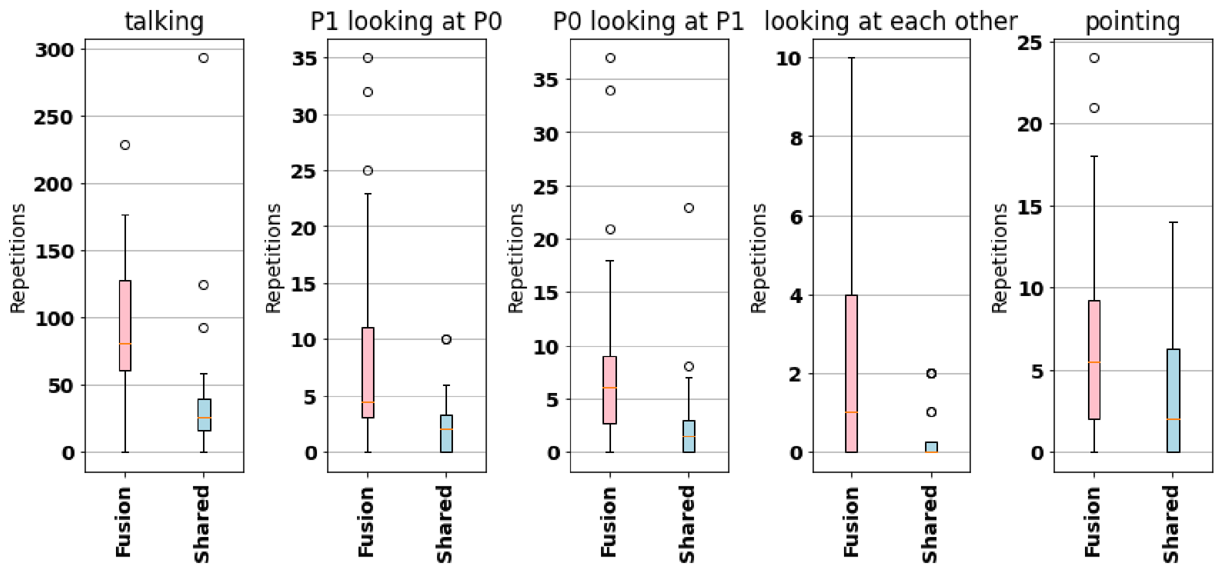



Figure 5.7: Comparison of Video features between the Shared and Fusion conditions

conducted a statistical test on the annotated video features (behavioural events) to investigate if there is a difference between the Shared and Fusion conditions. Since the features are independent, we applied the paired t-test for each feature, and found a significant difference – participants talked significantly more (p-value $< 0.001$), looked at each other more ('P1 looking at P0': p-value $< 0.01$, 'P0 looking at P1': p-value $< 0.005$, 'looking at each other': $p < 0.005$), and pointed more ($p < 0.01$) in the Fusion condition (see Fig. 5.7) compared to the Shared condition. This shows increased communication for this condition.

### 5.4.6 Questionnaire Results

We collected the questionnaire data of 48 participants in this study. Due to technical failure, we failed to store the answer of three individuals, to one question each. Those three participants were removed from the pool in both conditions for the missing question.

However, we used their answers for the remainder of the questions. We found the following results from analyzing the responses:

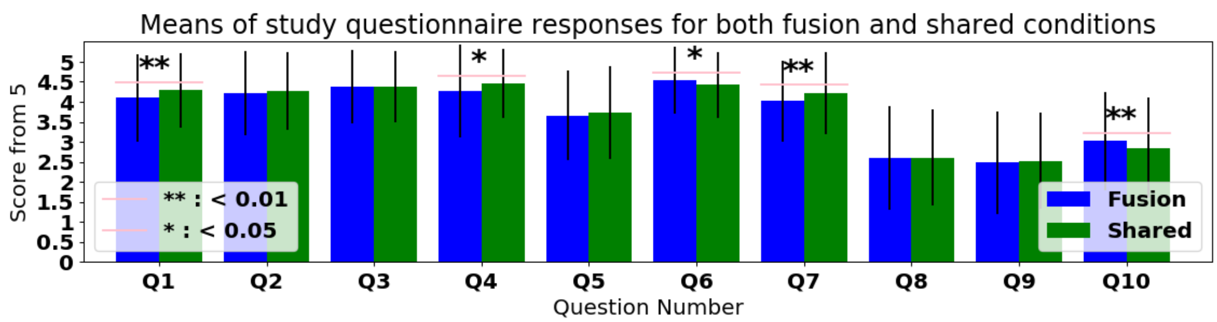



Figure 5.8: The average value of responses to the questionnaire (Q1 to Q10, table 5.1) for both Fusion and Shared conditions, the stars indicate if there is a significant difference between the two conditions, with the corresponding p value, $p < 0.01$ **; $p < 0.05$ *

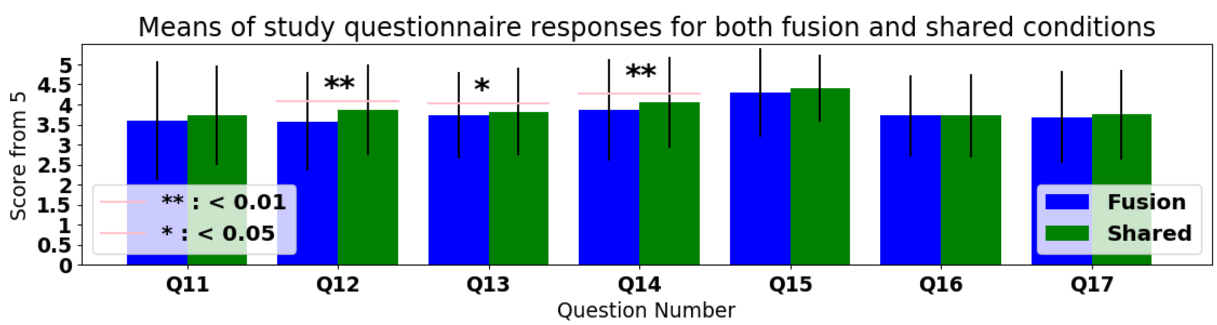



Figure 5.9: The average value of responses to the questionnaire (Q11 to Q17, table 5.1) for both Fusion and Shared conditions, the stars indicate if there is a significant difference between the two conditions, with the corresponding p value, $p < 0.01$ **; $p < 0.05$ *

- The Fusion condition was more challenging for participants, but the Shared condition was perceived as more pleasurable and fun, and the participants thought they were better at it and felt more capable.
- They felt more connected and cooperated more in the Fusion condition.
- Participants liked both conditions equally. The amount of confusion and frustration in both conditions were at similar levels.

- The participants felt challenged in both conditions, but felt less challenged during the Shared condition (on a scale from 1 to 5, the average score given to how challenging it is to use the robot, was 3.03 in the Fusion condition, and 2.85 in the shard condition).
- Participants felt slightly more competent in the Shared condition (The average score in the Fusion condition was 3.69 while it was 3.75 in the Shared condition, the score ranges were 1 to 5), and assumed they were able to get better at it more.

Figures 5.8 and 5.9 display the average responses for each question.
To test if there is a significant difference between the Shared and Fusion condition, we conducted a paired t-test on the responses for each question. The results showed a significant difference in the mean Q4, Q6, and Q13 ($p < 0.05$) and Q1, Q7, Q10, Q12, Q14 ($p < 0.01$) between the Shared and Fusion conditions (See table 5.1 for questionnaire items). The participants answered the questions consistently in both conditions (Cronbachs's $\alpha$ measure: 0.83 with a confidence level of 0.01).

### 5.4.7 Heart-rate results

We analyzed the Resting and Stimulated Level heart rate of each participant. A t-test on the heart rates revealed a significant difference between the Resting Level and the Stimulated Level (Resting Level mean: 68.72, Stimulated Level mean: 73.67, p-value $<$ 0.001).
The trend of each moving average heart rate data is then observed, and we constructed participant Stimulated Level plots for the two experimental conditions (see plots. 5.12, 5.15, 5.18, and 5.21 the heart rate during both conditions for four participants, showing four different patterns of heart rate observed). We observed that, among 39 participant (for the remainder of the participants the heart rate recordings of one or both conditions were missing), for 23 participants, the average heart rate in the Fusion condition was greater than in the Shared condition. The average heart rate in the Shared condition, for 22 participants, was less than the Stimulated Level and for 12 participants, it was even less than the Resting Level of the participant in charge of collecting and shooting the balls. This could be due to the fact that this participant only had limited game-play, only picking up and shooting the balls.
The average heart rate for Participant 45 in both conditions, shows a different trend. While the heart rate sometimes reached the Stimulated Level, during the Fusion condition, the average was less than the Resting Level. The heart rate is closer to the Stimulated Level in the Fusion condition, however, in the Shared condition, the heart rate is close to the

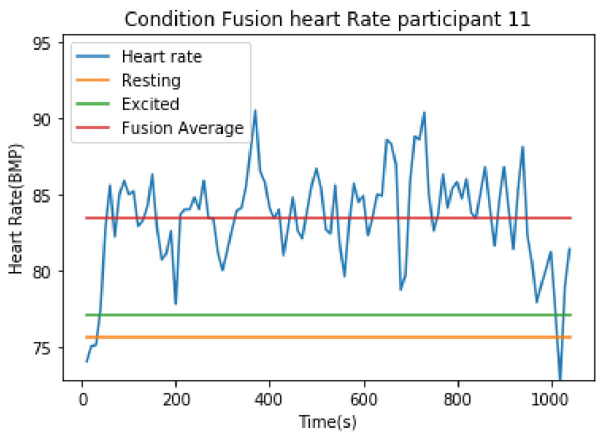



Figure 5.10: Fusion condition

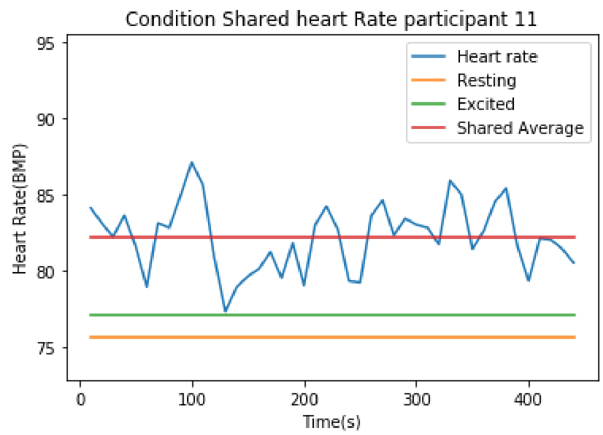



Figure 5.11: Shared condition

Figure 5.12: The heart rate plots for participant 11, the green line shows the Stimulated Level, the orange line shows the Resting Level, and the red line is the average heart rate in each condition

Resting Level or below that. This can be explained by less game play during the Shared condition.
The average heart rate in the Fusion condition was 83.21 (std= 10.6) which is slightly greater than this value in the Shared condition (mean= 82.25, std= 10), while it was 81.93 in the baseline condition. To compare the Fusion and Shared condition, we ran a t-test that showed a significant difference between the rate of Excited Intervals in the Fusion condition and Shared (The percentage of Excited Intervals in the Fusion condition was 0.72, while it was 0.62 in the Shared condition.)

We observed that most participants, with a high frequency of Excited Intervals, responded positively to the questions in the questionnaire related to engagement such as 'The activity was fun', or 'The activity was pleasurable', and suggest that heart rate and frequency of Excited Intervals might indicate engagement during the activity. However, it requires more precise measures of heart rate, and engagement in future studies.

## 5.5 Discussion

In this study, we presented a user study where pairs of participants played together through a robot play-mediator. The game involved collaborative navigation and ball handling in

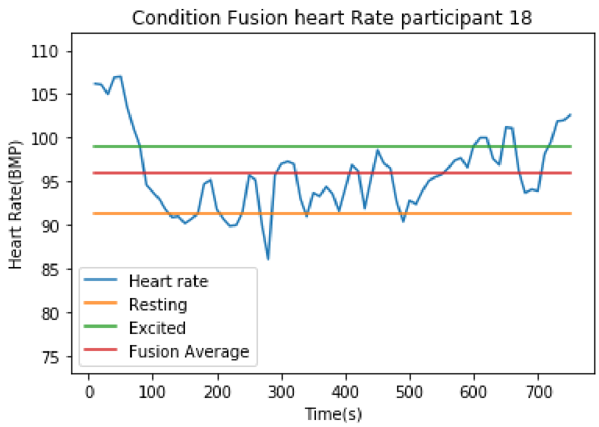



Figure 5.13: Fusion condition

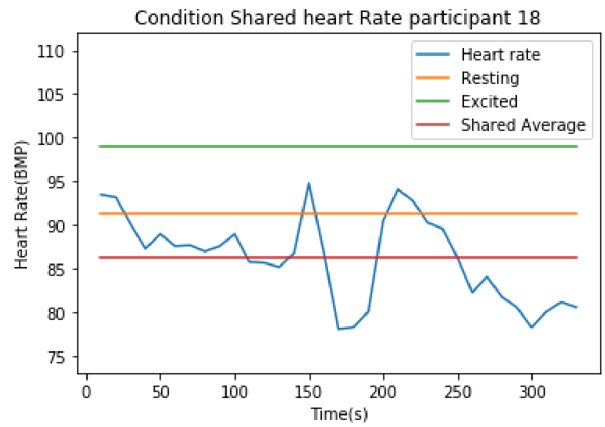



Figure 5.14: Shared condition

Figure 5.15: The heart rate plots for participant 18, the green line shows the Stimulated Level, the orange line shows the Resting Level, and the red line is the average heart rate in each condition

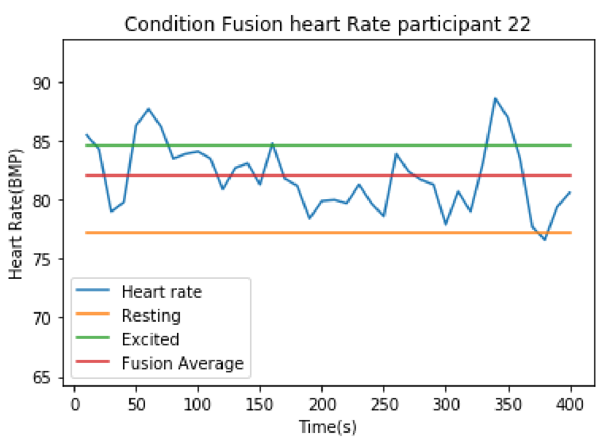



Figure 5.16: Fusion condition

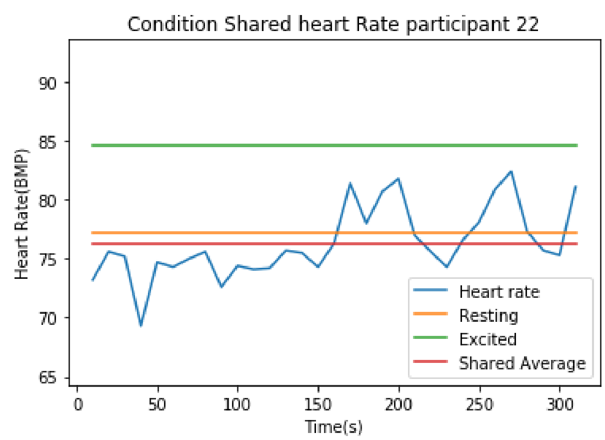



Figure 5.17: Shared condition

Figure 5.18: The heart rate plots for participant 22, the green line shows the Stimulated Level, the orange line shows the Resting Level, and the red line is the average heart rate in each condition

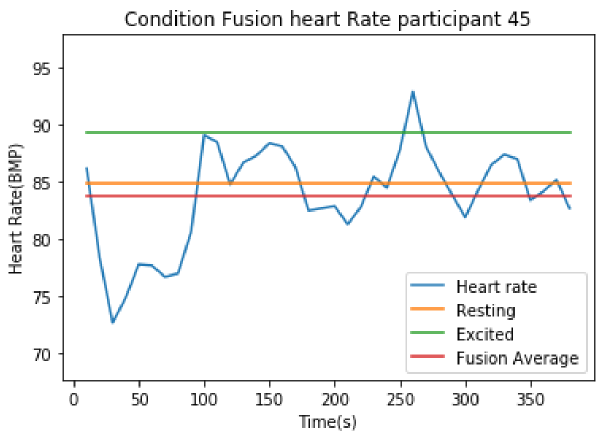



Figure 5.19: Fusion condition

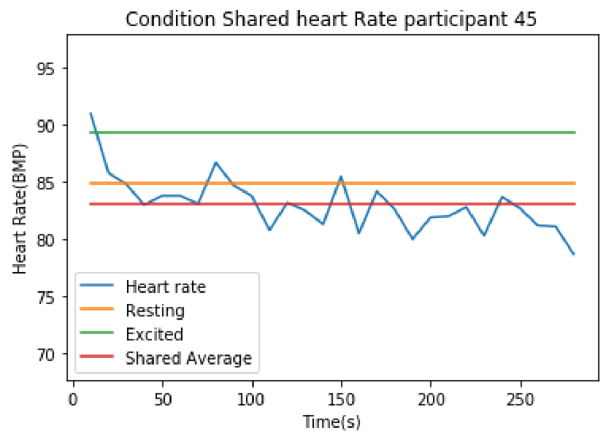



Figure 5.20: Shared condition

Figure 5.21: The heart rate plots for participant 45, the green line shows the Stimulated Level, the orange line shows the Resting Level, and the red line is the average heart rate in each condition

two conditions, which explored different types of collaboration: sharing tasks (Shared condition) or simultaneously performing a joint task (Fusion condition). Here, we focused on how both players collaborated with each other, in terms of coordination and communication using video, heart rate, and joystick data. Our results suggest that the Fusion condition required more corporation and collaboration, since it was more challenging. The questionnaire results revealed that participants enjoyed the Shared condition more, while they felt more connected throughout the Fusion condition. The joystick commands were random, however, the frequency and magnitude of joystick commands showed significant differences between conditions, possibly due to the collaboration of partners in the game. We collected the heart rate data and hypothesized to find a relationship between heart rate, joy stick commands, and engagement. However, we didn't observe any patterns between the questionnaire data (regarding enjoyment) and heart rate. We found that the number of Excited Intervals are significantly greater in the Fusion condition than the Shared condition, while, the questionnaire data showed they enjoyed the Shared condition more. A possible explanation for the higher Excited intervals in the Fusion condition could be that participants felt more challenged, and the questionnaire results also supports that the Shared condition was significantly less challenging for participants. Overall, the challenging task promoted more communication, but was not necessarily more enjoyable. Further research is required to clarify the relation of engagement, enjoyment, and other measures during collaborative games.

## 5.6 Limitations and Future Work

Measuring different types of data, including physiological, poses some challenges and limitations for data recording and analysis. Our participants were university students, their age could influence the heart rate level, besides the Resting Level and Stimulated Level, could be influenced by the activities they were doing before the study. Moreover, the collection of heart rate of the two participants, were not synchronized and caused some challenges in data analysis.

In future studies, it will be useful to 1) repeat the same study, and recruit children with upper-limb disabilities to participate, 2) synchronize the collection of heart rate and joystick data

# Chapter 6

# Conclusion

## 6.1 Summary of Findings:

In this chapter, the findings of each study and the corresponding research questions are discussed:

### 6.1.1 Findings of Study 1

In the first study, we explored how a social robot's presence can impact students' off-task behaviours. Moreover, we investigated how re-direction strategies taught by the robot can assist students with learning disabilities (LD) in staying on-task when learning becomes difficult and how students met their learning goals.

**Would the presence of the robot support on-task behaviours and learning goal completion for students?**
Students with LD are complex learners who often struggle with the need to attend extra one-to-one instructional sessions in addition to school. Due to the variety of needs and challenges of students with LD, it is difficult to find interventions and supports that can work effectively for a broad range of students and be used willingly and with fidelity by a range of specialized instructors. However, the findings of this study suggest that the social robot supported and, in some cases, improved student on-task behaviour and goal completion.
**What impact did the RS provided by the robot have on redirecting the students' focus back on a challenging task?**

We observed that instructors were able to implement the social robot into an existing educational program for students with learning disabilities, and the robot was an effective tool for students attending one-to-one instructions with an instructor, and the results suggest the RS exhibited by the robot helped the students.

These initial findings of the first study, suggest that a social robot may be an effective educational tool for students with LD attending one-to-one sessions and that further research is needed to determine the efficacy of the intervention and the experience of instructors working with the robot as part of their pedagogical practice.

### 6.1.2 Findings of Study 2

Building from these initial findings, a larger field study that addresses many of the limitations of the first study was conducted. In the second study, we aimed to evaluate the acceptance of the social robot by the users, i.e. students and instructors.

**What is the level of technology acceptance the robot achieves with both students and instructors?**
The responses of the instructors through open-ended questions and questionnaires suggest that they had accepted the robot as a tool in their lessons to a great extent. Similarly, the students perceived the robot as intelligent, friendly, and enjoyable, while simultaneously, showing a willingness to use the robot in the future.
**How does the use of a robot influence engagement and off-task behaviours over multiple sessions?**
In order to answer this research question, we compared the intervention and control conditions. The results indicated that the robot helped students display fewer off-task behaviours and boosted their engagement during the intervention.
Robot-mediated instruction provides many challenges. Due to the wide range of needs of students with LD, it is challenging to find an intervention that suits all students. There are more complex assistive tools that can support students better, but they usually require some level of technical knowledge, which is not desirable [118].
Despite all the shortcomings, the results of the first and second study suggest two major findings: 1) the social robot can assist student engagement and reduce off-task behaviours for students with learning disabilities, 2) Instructors can integrate the robot into the existing program with minimal technical background and training, and they generally hold a positive attitude towards the use of the robot, and its impact on students.

### 6.1.3 Findings of Study 3

Next, we moved on to another aspect of assistive robots. The third study aimed to investigate the use of a robot, in play and games for children with special needs. We designed an experiment to explore the play dynamics of two children with upper-limb disorders, playing a collaborative game with the Myjay robot. However, due to COVID-19 restrictions in recruiting children, the study was conducted with university students to get preliminary results.

**Which collaborative robot control condition best promotes collaboration among the participants?**
We observed that participants cooperated better and felt more connected in the Fusion condition, though they found the Fusion condition more challenging. This does not support our hypothesis that participants might enjoy the Fusion condition better, however, this result could be explained by the increased difficulty of the Fusion condition which also promoted better collaboration.
**Which robot control condition provides the best game experience in terms of enjoyment?**
Preliminary results confirmed our hypothesis that the Fusion condition promoted communication between the participants better than the shared condition, probably because the latter condition was more challenging. Questionnaire results indicated that the participants enjoyed the activity more in the shared condition.
Overall, joystick coordination was quite low, as most participants gave random commands about half of the time, hoping to match their partner's command. Moreover, in the shared condition, participants did not always respect their assigned tasks.
**Which strategies do participants employ to achieve collaboration?**
In terms of play dynamics, the video analysis revealed that participants communicated more, through speech, gaze and gesture, in the Fusion condition. Moreover, an interaction leader would usually emerge, and they would announce commands out loud or place their joystick in front of their partner, so that they could copy the commands.
We observed that:
1) Participants use different strategies to communicate in the collaborative game, however some common behaviours are found 2) a challenging task promotes better communication among the participants.

## 6.2 Major Contributions to Knowledge

This research contributes to assistive robots and how they can benefit children with special needs with challenges they face in their life, with a focus on children with learning disabilities and upper-limb impairments. We investigated their needs and proposed robotic interventions that can assist them in specific aspects of life. We conducted three user-studies, (two studies related to learning disabilities and the other targeted upper-limb disorders) to explore our research questions.

- The first study integrated the use of a social robot into an already existing program for students with learning disabilities, without any change to their curriculum and learning goals. We did not change the goals of the instructional program or the curriculum, therefore the robot was added into a wide range of students' programs to accommodate the possible scenarios that students and instructors in a typical instruction session.
- The second study was conducted to expand the scope of the previous study. Besides integrating a social robot into the already existing program, it presented a program with more interactive games and activities, to better meet the needs of different participants and evaluated users (students and instructors) perspective toward technology.
- The third study, with a focus on play and robotics, presented game scenarios to promote collaboration between two participants through a robot as a play mediator using joysticks. The play dynamics, observed in the games, can be further used to design enjoyable games and therapy scenarios for children with upper-limb disorders.

Overall, our findings contribute to assistive technology and its benefits for children with special needs, in 1) exploring the applications of assistive robotics in real world scenarios, while the robot was not used as a teacher, but was used as a tool and 2) presenting robotic interventions to support children's needs and provide enjoyable experiences for them in aspects that have not been explored before.

## 6.3 Limitations and Future Work

Conducting research in the field of assistive technologies and children with special needs requires considerations that pose many challenges for the recruitment process, e.g. age

requirements, range of variability of disorders, and creating a safe and engaging experience. Moreover, Covid-19 created significant challenges, such as cancelling sessions due to sickness, pausing studies or moving to online lessons, and vaccination requirements. For example, some of our participants cancelled their sessions, therefore some participants didn't have as many sessions as others, which made the analysis challenging. Besides, we were not allowed to conduct in-person studies with sensitive groups, and we were not able to recruit children with disabilities, to participate in our study.
In few cases, the devices used in the experiments failed to record the data or the data recorded was not synchronized with other types of data.

We observed that due to the wide range of needs of participants, it was challenging to consider all their needs and fit them into one activity. We need to take into account a broader range of users' needs and expectations to offer an individualized intervention. Besides, the response and attitude toward a robotic intervention, can change over time.
Regarding future work to extend and confirm the results obtained in the three studies, we suggest:

- conducting experiments with a larger sample size, and for a longer duration. In order to evaluate how the effect of the robotic intervention on children, is changing over time, with regard to the fact that each individual has their own needs, and
- design a variety of interaction scenarios, for children, to include the various needs of children, to be able to offer individualized support that targets their unique needs.
- One could automate data recording and synchronization of different data types measured to minimize the efforts of experiment conductors to avoid any possible loss of data, for future studies, and
- conduct follow-up experiments to examine if the benefits persist.

# References


[1] Ghaleb Alnahdi. Assistive technology in special education and the universal design for learning. *Turkish Online Journal of Educational Technology-TOJET*, 13(2):18–23, 2014.

[2] Sandra Alper and Sahoby Raharinirina. Assistive technology for individuals with disabilities: A review and synthesis of the literature. *Journal of Special Education Technology*, 21(2):47–64, 2006.

[3] Angelos Amanatiadis, Vassilis G Kaburlasos, Ch Dardani, and Savvas A Chatzichristofis. Interactive social robots in special education. In *2017 IEEE 7th International Conference on consumer electronics-Berlin (ICCE-Berlin)*, pages 126–129. IEEE, 2017.

[4] Paula Amorim, Beatriz Sousa Santos, Paulo Dias, Samuel Silva, and Henrique Martins. Serious games for stroke telerehabilitation of upper limb-a review for future research. *International journal of telerehabilitation*, 12(2):65, 2020.

[5] Comfort Atanga, Beth A Jones, Lacy E Krueger, and Shulan Lu. Teachers of students with learning disabilities: Assistive technology knowledge, perceptions, interests, and barriers. *Journal of Special Education Technology*, 35(4):236–248, 2020.

[6] Negin Azizi, Shruti Chandra, Mike Gray, Jennifer Fane, Melissa Sager, and Kerstin Dautenhahn. User evaluation of social robots as a tool in one-to-one instructional settings for students with learning disabilities, 2022. To appear in the Internation Conference on Social Robotics, 13-16 December, 2022, Italy.

[7] Negin Azizi, Shruti Chandra, Mike Gray, Melissa Sager, Jennifer Fane, and Kerstin Dautenhahn. An initial investigation into the use of social robots within an existing

educational program for students with learning disabilities. In *2022 31st IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*, pages 1490–1497, 2022.

[8] Negin Azizi, Kevin Fan, Melanie Jouaiti, and Kerstin Dautenhahn. Play dynamics in a collaborative game with a robot as a play-mediator, 2022. To appear in the Internation Conference on Social Robotics, 13-16 December, 2022, Italy.

[9] Nancy K Barga. Students with learning disabilities in education: Managing a disability. *Journal of learning disabilities*, 29(4):413–421, 1996.

[10] Gökçe Elif Baykal, Maarten Van Mechelen, and Eva Eriksson. Collaborative technologies for children with special needs: A systematic literature review. In *Proceedings of the 2020 CHI conference on human factors in computing systems*, pages 1–13, 2020.

[11] Tony Belpaeme, James Kennedy, Aditi Ramachandran, Brian Scassellati, and Fumihide Tanaka. Social robots for education: A review. *Science robotics*, 3(21), 2018.

[12] Fatimaezzahra Benmarrakchi, Nihal Ouherrou, Oussama Elhammoumi, and Jamal El Kafi. An innovative approach to involve students with learning disabilities in intelligent learning systems. In *International Conference on Advanced Intelligent Systems for Sustainable Development*, pages 39–50. Springer, 2018.

[13] Chris Berka, Daniel J Levendowski, Michelle N Lumicao, Alan Yau, Gene Davis, Vladimir T Zivkovic, Richard E Olmstead, Patrice D Tremoulet, and Patrick L Craven. Eeg correlates of task engagement and mental workload in vigilance, learning, and memory tasks. *Aviation, space, and environmental medicine*, 78(5):B231–B244, 2007.

[14] Serenella Besio, Daniela Bulgarelli, and Vaska Stancheva-Popkostadinova. *Play development in children with disabilties*. De Gruyter Open Poland, 2017.

[15] B. Bonnechère, B. Jansen, L. Omelina, M. Degelaen, V. Wermenbol, M. Rooze, and S. Van Sint Jan. Can serious games be incorporated with conventional treatment of children with cerebral palsy? a review. *Research in Developmental Disabilities*, 35(8):1899–1913, 2014.

[16] Fernando HF Botelho. Childhood and assistive technology: Growing with opportunity, developing with technology. *Assistive Technology*, 33(sup1):87–93, 2021.

[17] Cynthia Breazeal, Kerstin Dautenhahn, and Takayuki Kanda. Social robotics. *Springer handbook of robotics*, pages 1935–1972, 2016.

[18] Daniela Bulgarelli, Nicole Bianquin, Serenella Besio, and Paola Molina. Children with cerebral palsy playing with mainstream robotic toys: Playfulness and environmental supportiveness. *Frontiers in psychology*, page 1814, 2018.

[19] Gerhard Büttner and Marcus Hasselhorn. Learning disabilities: Debates on definitions, causes, subtypes, and responses. *International Journal of Disability, Development and Education*, 58(1):75–87, 2011.

[20] John Cairney, Scott Veldhuizen, M Christine Rodriguez, Sara King-Dowling, Matthew Y Kwan, Terrance Wade, David Price, Cheryl Missiuna, and Brian Timmons. Cohort profile: the canadian coordination and activity tracking in children (catch) longitudinal cohort. *BMJ open*, 9(9):e029784, 2019.

[21] Luis Vicente Calderita, Luis J Manso, Pablo Bustos, Cristina Suárez-Mejías, Fernando Fernández, and Antonio Bandera. Therapist: towards an autonomous socially interactive robot for motor and neurorehabilitation therapies for children. *JMIR rehabilitation and assistive technologies*, 1(1):e3151, 2014.

[22] Shruti Chandra, Pierre Dillenbourg, and Ana Paiva. Classification of children's handwriting errors for the design of an educational co-writer robotic peer. In *Proceedings of the 2017 Conference on Interaction Design and Children*, pages 215–225, 2017.

[23] Shruti Chandra, Pierre Dillenbourg, and Ana Paiva. Children teach handwriting to a social robot with different learning competencies. *International Journal of Social Robotics*, 12(3):721–748, 2020.

[24] Caitlyn Clabaugh and Maja Matarić. Escaping oz: Autonomy in socially assistive robotics. *Annual Review of Control, Robotics, and Autonomous Systems*, 2:33–61, 2019.

[25] Daniela Conti, Santo Di Nuovo, Serafino Buono, and Alessandro Di Nuovo. Robots in education and care of children with developmental disabilities: a study on acceptance by experienced and future professionals. *International Journal of Social Robotics*, 9(1):51–62, 2017.

[26] Al Cook, Pedro Encarnação, and Kim Adams. Robots: Assistive technologies for play, learning and cognitive development. *Technology and Disability*, 22(3):127–145, 2010.

[27] Enrique Coronado, Fulvio Mastrogiovanni, Bipin Indurkhya, and Gentiane Venture. Visual programming environments for end-user development of intelligent and social robots, a systematic review. *Journal of Computer Languages*, 58:100970, 2020.

[28] Diana K Darnell and Paul A Krieg. Student engagement, assessed using heart rate, shows no reset following active learning sessions in lectures. *PloS one*, 14(12):e0225709, 2019.

[29] Kerstin Dautenhahn. Socially intelligent robots: dimensions of human–robot interaction. *Philosophical transactions of the royal society B: Biological sciences*, 362(1480):679–704, 2007.

[30] Shayn Davidson. *A Multi-dimensional model of enjoyment: Development and validation of an enjoyment scale (ENJOY).* Embry-Riddle Aeronautical University, 2018.

[31] Fred D Davis, Richard P Bagozzi, and Paul R Warshaw. User acceptance of computer technology: A comparison of two theoretical models. *Management science*, 35(8):982–1003, 1989.

[32] Larry W Desch, Deborah Gaebler-Spira, and Council on Children With Disabilities. Prescribing assistive-technology systems: Focus on children with impaired communication. *Pediatrics*, 121(6):1271–1280, 2008.

[33] Silvia Di Battista, Monica Pivetti, Michele Moro, and Emanuele Menegatti. Teachers' opinions towards educational robotics for special needs students: An exploratory italian study. *Robotics*, 9(3):72, 2020.

[34] Laurel M Garrick Duhaney and Devon C Duhaney. Assistive technology: Meeting the needs of learners with disabilities. *International Journal of Instructional Media*, 27(4):393–393, 2000.

[35] George J DuPaul, Matthew J Gormley, and Seth D Laracy. Comorbidity of ld and adhd: Implications of dsm-5 for assessment and treatment. *Journal of learning disabilities*, 46(1):43–51, 2013.

[36] Pedro Encarnação and Albert Cook. Robotic assistive technologies: Principles and practice. 2017.

[37] D. Feil-Seifer and M.J. Mataric. Defining socially assistive robotics. In *9th International Conference on Rehabilitation Robotics, 2005. ICORR 2005.*, pages 465–468, 2005.

[38] David Feil-Seifer and Maja J Matarić. Socially assistive robotics. *IEEE Robotics & Automation Magazine*, 18(1):24–31, 2011.

[39] Karen E Forgrave. Assistive technology: Empowering students with learning disabilities. *The Clearing House*, 75(3):122–126, 2002.

[40] Thomas Franke, Christiane Attig, and Daniel Wessel. A personal resource for technology interaction: development and validation of the affinity for technology interaction (ati) scale. *International Journal of Human–Computer Interaction*, 35(6):456–467, 2019.

[41] Marina Fridin. Storytelling by a kindergarten social assistive robot: A tool for constructive learning in preschool education. *Computers & education*, 70:53–64, 2014.

[42] Marina Fridin and Mark Belokopytov. Robotics agent coacher for cp motor function (rac cp fun). *Robotica*, 32(8):1265–1279, 2014.

[43] Daniel Gábana Arellano, Laurissa Tokarchuk, and Hatice Gunes. Measuring affective, physiological and behavioural differences in solo, competitive and collaborative games. In *International conference on intelligent technologies for interactive entertainment*, pages 184–193. Springer, 2016.

[44] Aimi Shazwani Ghazali, Jaap Ham, Emilia Barakova, and Panos Markopoulos. Persuasive robots acceptance model (pram): roles of social responses within the acceptance model of persuasive robots. *International Journal of Social Robotics*, 12(5):1075–1092, 2020.

[45] Ken Goldberg and Billy Chen. Collaborative control of robot motion: Robustness to error. In *Proceedings 2001 IEEE/RSJ International Conference on Intelligent Robots and Systems. Expanding the Societal Role of Robotics in the the Next Millennium (Cat. No. 01CH37180)*, volume 2, pages 655–660. IEEE, 2001.

[46] Roberta J Goldberg, Eleanor L Higgins, Marshall H Raskind, and Kenneth L Herman. Predictors of success in individuals with learning disabilities: A qualitative analysis of a 20-year longitudinal study. *Learning Disabilities Research & Practice*, 18(4):222–236, 2003.

[47] Víctor Gonzalez-Pacheco, Arnaud Ramey, Fernando Alonso-Martín, A Castro-Gonzalez, and Miguel A Salichs. Maggie: A social robot as a gaming platform. *International Journal of Social Robotics*, 3(4):371–381, 2011.

[48] Elena L Grigorenko, Donald L Compton, Lynn S Fuchs, Richard K Wagner, Erik G Willcutt, and Jack M Fletcher. Understanding, educating, and supporting children with specific learning disabilities: 50 years of science and practice. *American Psychologist*, 75(1):37, 2020.

[49] Arzu Guneysu Ozgur, Maximilian Jonas Wessel, Wafa Johal, Kshitij Sharma, Ayberk Özgür, Philippe Vuadens, Francesco Mondada, Friedhelm Christoph Hummel, and Pierre Dillenbourg. Iterative design of an upper limb rehabilitation game with tangible robots. In *Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction*, pages 241–250, 2018.

[50] Daniel P Hallahan, Paige C Pullen, and Devery Ward. A brief history of the field of learning disabilities. 2014.

[51] Ibrahim A Hameed, Girts Strazdins, Håvard AM Hatlemark, Ivar S Jakobsen, and John O Damdam. Robots that can mix serious with fun. In *International Conference on Advanced Machine Learning Technologies and Applications*, pages 595–604. Springer, 2018.

[52] Markus Häring, Dieta Kuchenbrandt, and Elisabeth André. Would you like to play with me? how robots' group membership and task features influence human–robot interaction. In *2014 9th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, pages 9–16. IEEE, 2014.

[53] Ahmed Elhassan Hamid Hassan. Emotional and behavioral problems of children with learning disabilities. *Journal of Educational Policy and Entrepreneurial Research (JEPER)*, 2(10):66–74, 2015.

[54] Hamilton A Hernandez, TC Nicholas Graham, Darcy Fehlings, Lauren Switzer, Zi Ye, Quentin Bellay, Md Ameer Hamza, Cheryl Savery, and Tadeusz Stach. Design of an exergaming station for children with cerebral palsy. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 2619–2628, 2012.

[55] Jesper F Hopstaken, Dimitri Van Der Linden, Arnold B Bakker, and Michiel AJ Kompier. A multifaceted investigation of the link between mental fatigue and task disengagement. *Psychophysiology*, 52(3):305–315, 2015.

[56] Jalal Ismaili and El Houcine Ouazzani Ibrahimi. Mobile learning as alternative to assistive technology devices for special needs students. *Education and Information Technologies*, 22(3):883–899, 2017.

[57] Daniela Jeder. Practical aspects of the continuous training activities regarding the learning difficulties. *Procedia-Social and Behavioral Sciences*, 116:2125–2130, 2014.

[58] Melanie Jouaiti, Negin Azizi, Steven Lawrence, and Kerstin Dautenhahn. Towards developing adaptive robot controllers for children with upper limb impairments - initial data collection and analysis, 2022. To appear in the Internation Conference on Social Robotics, 13-16 December, 2022, Italy.

[59] Malte Jung and Pamela Hinds. Robots in the wild: A time for more robust theories of human-robot interaction, 2018.

[60] Elpida Karageorgiou, Efrosyni Kourampa, Athanasia-Tania Papanikolaou, Petros Kechayas, Eleftheria Avramidou, Rafailia-Androniki Sabri, Chris Lytridis, George A Papakostas, and Vassilis G Kaburlasos. Development of educational scenarios for child-robot interaction: The case of learning disabilities. In *International Conference on Robotics in Education (RiE)*, pages 26–33. Springer, 2021.

[61] Amanda Kirby and David A Sugden. Children with developmental coordination disorders. *Journal of the Royal Society of Medicine*, 100(4):182–186, 2007.

[62] Elly A Konijn, Matthijs Smakman, and Rianne van den Berghe. Use of robots in education. *The Int. Encyclopedia of Media Psychology*, pages 1–8, 2020.

[63] Hatice Kose-Bagci, Ester Ferrari, Kerstin Dautenhahn, Dag Sverre Syrdal, and Chrystopher L Nehaniv. Effects of embodiment and gestures on social interaction in drumming games with a humanoid robot. *Advanced Robotics*, 23(14):1951–1996, 2009.

[64] Yiannis Koumpouros. A systematic review on existing measures for the subjective assessment of rehabilitation and assistive robot devices. *Journal of healthcare engineering*, 2016, 2016.

[65] Lisa Kovac. Definitions of disability across canada. https://www.aoda.ca/definitions-of-disability-across-canada/, January 2021.

[66] S Krishnaswamy, L Shriber, and Govindarajan Srimathveeravalli. The design and efficacy of a robot-mediated visual motor program for children learning disabilities. *Journal of computer assisted learning*, 30(2):121–131, 2014.

[67] Leah Kuypers. The zones of regulation. *San Jose: Think Social Publishing*, 2011.

[68] Andrea Catalina Ladino Nocua, Joan Paola Cruz Gonzalez, Ivonne Angelica Castiblanco Jimenez, Juan Sebastian Gomez Acevedo, Federica Marcolin, and Enrico Vezzetti. Assessment of cognitive student engagement using heart rate data in distance learning during covid-19. *Education Sciences*, 11(9):540, 2021.

[69] Lieven Lagae. Learning disabilities: definitions, epidemiology, diagnosis, and intervention strategies. *Pediatric Clinics of North America*, 55(6):1259–1268, 2008.

[70] Rena B Lewis and Rena B Lewis. Assistive technology and learning disabilities: Today's realities and tomorrow's promises. *Journal of learning disabilities*, 31(1):16–26, 1998.

[71] G Reid Lyon, Jack M Fletcher, Sally E Shaywitz, Bennett A Shaywitz, Joseph K Torgesen, Frank B Wood, Ann Schulte, and Richard Olson. Rethinking learning disabilities. *Rethinking special education for a new century*, pages 259–287, 2001.

[72] Chris Lytridis, Christos Bazinas, George A Papakostas, and Vassilis Kaburlasos. On measuring engagement level during child-robot interaction in education. In *International Conference on Robotics in Education (RiE)*, pages 3–13. Springer, 2019.

[73] Hamza Mahdi, Shahed Saleh, Elaheh Sanoubari, and Kerstin Dautenhahn. User-centered social robot design: Involving children with special needs in an online world. In *2021 30th IEEE International; Conference on Robot and Human Interactive Communication (RO-MAN)*, pages 844–851. IEEE, 2021.

[74] Hamza Mahdi, Shahed Saleh, Omar Shariff, and Kerstin Dautenhahn. Creating myjay: A new design for robot-assisted play for children with physical special needs. In *International Confrence on Social Robotics*, pages 676–687. Springer, 2020.

[75] Karl J Maier, Shari R Waldstein, and Stephen J Synowski. Relation of cognitive appraisal to cardiovascular reactivity, affect, and task engagement. *Annals of Behavioral Medicine*, 26(1):32–41, 2003.

[76] Italo Marroquin. *The Effects of Mindfulness as An Intervention to Decrease Off-Task Behaviors in Adult Students with Intellectual Disabilities.* PhD thesis, California State University Dominguez Hills, 2018.

[77] Nancy Mather, Sam Goldstein, and Katie Eklund. Learning disabilities and challenging behaviors. *Baltimore, MD: PH Brookes*, 2001.

[78] Judith L Meece, Phyllis C Blumenfeld, and Rick H Hoyle. Students' goal orientations and cognitive engagement in classroom activities. *Journal of educational psychology*, 80(4):514, 1988.

[79] Alison L Miller, Ashley N Gearhardt, Emily M Fredericks, Benjamin Katz, Lilly Fink Shapiro, Kelsie Holden, Niko Kaciroti, Richard Gonzalez, Christine Hunter, and Julie C Lumeng. Targeting self-regulation to promote health behaviors in children. *Behaviour research and therapy*, 101:71–81, 2018.

[80] John Edison Muñoz and Kerstin Dautenhahn. Robo ludens: A game design taxonomy for multiplayer games using socially interactive robots. *ACM Transactions on Human-Robot Interaction (THRI)*, 10(4):1–28, 2021.

[81] Christine E Murray, Erin L Kelley-Soderholm, and Thomas L Murray Jr. Strengths, challenges, and relational processes in families of children with congenital upper limb differences. *Families, Systems, & Health*, 25(3):276, 2007.

[82] Domen Novak, Aniket Nagle, Urs Keller, and Robert Riener. Increasing motivation in robot-aided arm rehabilitation with competitive and cooperative gameplay. *Journal of neuroengineering and rehabilitation*, 11(1):1–15, 2014.

[83] Edwin Daniel Oña, Carlos Balaguer, and Alberto Jardón. Towards a framework for rehabilitation and assessment of upper limb motor function based on serious games. In *2018 IEEE 6th International Conference on Serious Games and Applications for Health (SeGAH)*, pages 1–7. IEEE, 2018.

[84] Heather L. O'Brien, Paul Cairns, and Mark Hall. A practical approach to measuring user engagement with the refined user engagement scale (ues) and new ues short form. *International Journal of Human-Computer Studies*, 112:28–39, 2018.

[85] Fotios Papadopoulos, Kerstin Dautenhahn, and Wan Ching Ho. Exploring the use of robots as social mediators in a remote human-human collaborative communication experiment. *Paladyn*, 3(1):1–10, 2012.

[86] George A Papakostas, George K Sidiropoulos, Chris Lytridis, Christos Bazinas, Vassilis G Kaburlasos, Efi Kourampa, Elpida Karageorgiou, Petros Kechayas, and Maria T Papadopoulou. Estimating children engagement interacting with robots in special education using machine learning. *Mathematical Problems in Engineering*, 2021, 2021.

[87] George A Papakostas, George K Sidiropoulos, Cristina I Papadopoulou, Eleni Vrochidou, Vassilis G Kaburlasos, Maria T Papadopoulou, Vasiliki Holeva, Vasiliki-Aliki Nikopoulou, and Nikolaos Dalivigkas. Social robots in special education: A systematic review. *Electronics*, 10(12):1398, 2021.

[88] Anna Pecchinenda. The affective significance of skin conductance activity during a difficult problem-solving task. *Cognition & Emotion*, 10(5):481–504, 1996.

[89] Bogi Perelmutter, Karla K McGregor, and Katherine R Gordon. Assistive technology interventions for adolescents and adults with learning disabilities: An evidence-based systematic review and meta-analysis. *Computers & education*, 114:139–163, 2017.

[90] Anne A Poulsen and Jenny M Ziviani. Can i play too? physical activity engagement of children with developmental coordination disorders. *Canadian Journal of Occupational Therapy*, 71(2):100–107, 2004.

[91] Daniel C Richardson, Nicole K Griffin, Lara Zaki, Auburn Stephenson, Jiachen Yan, Thomas Curry, Richard Noble, John Hogan, Jeremy I Skipper, and Joseph T Devlin. Engagement in video and audio narratives: contrasting self-report and physiological measures. *Scientific Reports*, 10(1):1–8, 2020.

[92] Jerome I Rotgans and Henk G Schmidt. Cognitive engagement in the problem-based learning classroom. *Advances in health sciences education*, 16(4):465–479, 2011.

[93] Jesús Sánchez-Martín, Florentina Cañada-Cañada, and María Antonia Dávila-Acedo. Just a game? gamifying a general science class at university: Collaborative and competitive work implications. *Thinking Skills and Creativity*, 26:51–59, 2017.

[94] Richard A Saudargas and Kathleen Zanolli. Momentary time sampling as an estimate of percentage time: A field validation. *Journal of Applied Behavior Analysis*, 23(4):533–537, 1990.

[95] Brian Scassellati, Laura Boccanfuso, Chien-Ming Huang, Marilena Mademtzi, Meiying Qin, Nicole Salomons, Pamela Ventola, and Frederick Shic. Improving social skills in children with asd using a long-term, in-home social robot. *Science Robotics*, 3(21), 2018.

[96] Phillip C Schlechty. *Working on the Work: An Action Plan for Teachers, Principals, and Superintendents. The Jossey-Bass Education Series.* ERIC, 2002.

[97] Dale H Schunk and Maria K DiBenedetto. Self-regulation, self-efficacy, and learning disabilities. 2021.

[98] S Senthil and Mu Lin Wong. Measuring students' engagement using wireless heart rate sensors. In *2017 International Conference On Smart Technologies For Smart Nation (SmartTechCon)*, pages 699–704. IEEE, 2017.

[99] Jainendra Shukla, Julián Cristiano, David Amela, Laia Anguera, Jaume Vergés-Llahí, and Domenec Puig. A case study of robot interaction among individuals with profound and multiple learning disabilities. In *International Conference on Social Robotics*, pages 613–622. Springer, 2015.

[100] Mary M Smyth and Heather I Anderson. Coping with clumsiness in the school playground: Social and physical play in children with coordination impairments. *British journal of developmental psychology*, 18(3):389–413, 2000.

[101] Stanford Artificial Intelligence Laboratory et al. Robotic operating system.

[102] Idor Svensson, Thomas Nordström, Emma Lindeblad, Stefan Gustafson, Marianne Björn, Christina Sand, Gunilla Almgren/Bäck, and Staffan Nilsson. Effects of assistive technology for students with reading and writing disabilities. *Disability and Rehabilitation: Assistive Technology*, 16(2):196–208, 2021.

[103] Dag Sverre Syrdal, Kerstin Dautenhahn, Ben Robins, Efstathia Karakosta, and Nan Cannon Jones. Kaspar in the wild: Experiences from deploying a small humanoid robot in a nursery school for children with autism. *Paladyn, Journal of Behavioral Robotics*, 11(1):301–326, 2020.

[104] Susan Sze. The effects of assistive technology on students with disabilities. *Journal of Educational Technology Systems*, 37(4):419–429, 2009.

[105] Adriana Tapus, Maja J Mataric, and Brian Scassellati. Socially assistive robotics [grand challenges of robotics]. *IEEE robotics & automation magazine*, 14(1):35–42, 2007.

[106] Jovica Tasevski, Milan Gnjatović, and Branislav Borovac. Assessing the children's receptivity to the robot marko. *Acta Polytechnica Hungarica*, 15(5):47–66, 2018.

[107] Leonard Tetzlaff, Florian Schmiedek, and Garvin Brod. Developing personalized education: A dynamic framework. *Educational Psychology Review*, 33(3):863–882, 2021.

[108] Ahmed Tlili, Vivien Lin, Nian-Shing Chen, and Ronghuai Huang. A systematic review on robot-assisted special education from the activity theory perspective. *Educational Technology & Society*, 23(3):95–109, 2020.

[109] Joseph K Torgesen. Learning disabilities: An historical and conceptual overview. *Learning about learning disabilities*, pages 3–40, 2004.

[110] Brianna Turba. *The Use of Movement Integration in a Fifth Grade Classroom to Reduce Off-task Behaviors at the Beginning of the Math Period*. PhD thesis, Caldwell University, 2019.

[111] Rianne van den Berghe, Josje Verhagen, Ora Oudgenoeg-Paz, Sanne Van der Ven, and Paul Leseman. Social robots for language learning: A review. *Review of Educational Research*, 89(2):259–295, 2019.

[112] Renée JF van den Heuvel, Monique AS Lexis, Gert Jan Gelderblom, Rianne ML Jansens, and Luc P de Witte. Robots and ict to support play in children with severe physical disabilities: a systematic review. *Disability and Rehabilitation: Assistive Technology*, 11(2):103–116, 2016.

[113] Sharon Vaughn and Sylvia Linan-Thompson. What is special about special education for students with learning disabilities? *The Journal of Special Education*, 37(3):140–147, 2003.

[114] Marynel Vázquez, Alexander May, Aaron Steinfeld, and Wei-Hsuan Chen. A deceptive robot referee in a multiplayer gaming environment. In *2011 international conference on collaboration technologies and systems (CTS)*, pages 204–211. IEEE, 2011.

[115] Viswanath Venkatesh and Hillol Bala. Technology acceptance model 3 and a research agenda on interventions. *Decision sciences*, 39(2):273–315, 2008.

[116] Viswanath Venkatesh, Michael G Morris, Gordon B Davis, and Fred D Davis. User acceptance of information technology: Toward a unified view. *MIS quarterly*, pages 425–478, 2003.

[117] Joshua Wainer, Ben Robins, Farshid Amirabdollahian, and Kerstin Dautenhahn. Using the humanoid robot kaspar to autonomously play triadic games and facilitate collaborative play among children with autism. *IEEE Transactions on Autonomous Mental Development*, 6(3):183–199, 2014.

[118] Eileen Winter, Aisling Costello, Moya O'Brien, and Grainne Hickey. Teachers' use of technology and the impact of covid-19. *Irish Educational Studies*, 40(2):235–246, 2021.

[119] Krista Coleman Wood, Corinna E Lathan, and Kenton R Kaufman. Feasibility of gestural feedback treatment for upper extremity movement in children with cerebral palsy. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 21(2):300–305, 2012.

[120] Haipeng Zeng, Xinhuan Shu, Yanbang Wang, Yong Wang, Liguo Zhang, Ting-Chuen Pong, and Huamin Qu. Emotioncues: Emotion-oriented visual summarization of classroom videos. *IEEE transactions on visualization and computer graphics*, 27(7):3168–3181, 2020.

[121] Yaoxin Zhang, Wenxu Song, Zhenlin Tan, Huilin Zhu, Yuyin Wang, Cheuk Man Lam, Yifang Weng, Sio Pan Hoi, Haoyang Lu, Bella Siu Man Chan, et al. Could social robots facilitate children with autism spectrum disorders in learning distrust and deception? *Computers in Human Behavior*, 98:140–149, 2019.

[122] Andrea N Zuniga. *Using Class Pass Intervention (CPI) to Decrease Disruptive Behavior in Children*. University of South Florida, 2019.

[123] M. Zyda. From visual simulation to virtual reality to games. *Computer*, 38(9):25–32, 2005.

# APPENDICES

# Appendix A

# Ethics Clearance Certificates

This chapter includes the ethics clearance for the second and third study. The first study was conducted remotely and with the advice of the Ethics Committee of the University of Waterloo, the collaboration did not require University of Waterloo approval.

## UNIVERSITY OF WATERLOO

### Notification of Ethics Clearance to Conduct Research with Human Participants

---

Principal Investigator: Kerstin Dautenhahn (Electrical and Computer Engineering)

Student investigator: Negin Azizi (Electrical and Computer Engineering)

Co-Investigator: Shruti Chandra (Electrical and Computer Engineering)

Co-Investigator: Jennifer Fane (Learning Disabilities Society(LDS))

Co-Investigator: Melissa Sager (Learning Disabilities Society(LDS))

Co-Investigator: Michael Gray (Learning Disbalities Society(LDS))

File #: 43223

Title: Evaluating the QT Robot's Impact on Student Engagement During One-to-One Instruction

---

The Human Research Ethics Board is pleased to inform you this study has been reviewed and given ethics clearance.

**Initial Approval Date: 09/23/21 (m/d/y)**

University of Waterloo Research Ethics Boards are composed in accordance with, and carry out their functions and operate in a manner consistent with, the institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS, 2nd edition), International Conference on Harmonization: Good Clinical Practice (ICH-GCP), the Ontario Personal Health Information Protection Act (PHIPA), the applicable laws and regulations of the province of Ontario. Both Boards are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (HREB) and IRB00007409 (CREB).

This study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

**Expiry Date: 09/24/22 (m/d/y)**

Multi-year research must be renewed at least once every 12 months unless a more frequent review has otherwise been specified. Studies will only be renewed if the renewal report is received and approved before the expiry date. Failure to submit renewal reports will result in the investigators being notified ethics clearance has been suspended and Research Finance being notified the ethics clearance is no longer valid.

Level of review: Delegated Review

Signed on behalf of the Human Research Ethics Board

Vanessa Buote, Ethics Advisor, vbuote@uwaterloo.ca, 519-888-4567, ext. 30321

This above named study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Documents reviewed and received ethics clearance for use in the study and/or received for information:

file: Data_Management_Plan.pdf

file: CONFIDENTIAL DISCLOSURE AGREEMENT.pdf

file: Pilot_Study_LDS_Approved_Ethics_Package.zip

file: Current_Study_LDS_Approved_Ethics_Package.zip

file: QTrobot_Safety_Guide.pdf

file: QTrobot-Product-Catalogue.pdf

file: QTrobot_Safety_Protocols.pdf

file: Consent_Form_Information_letter_Instructor .pdf

file: Consent_Form_Information_Letter_Parents.pdf

file: Pre_Session_Assent_Script.pdf

file: letter_of_appreciation.pdf

file: Student_Reflection_Worksheet.pdf

file: DIBELS_Test_Questions.zip

file: Dibels_Scoring_Guide.pdf

file: Study_Methods_Procedures.pdf

file: Questionnaire for Instructors.pdf

file: Questionnaire for Students.pdf

file: Introductory Email.pdf

file: Follow-Up Phone Script.pdf

Approved Protocol Version 3 in Research Ethics System

**This is an official document. Retain for your files.**

**You are responsible for obtaining any additional institutional approvals that might be required to complete this study.**

## UNIVERSITY OF WATERLOO

### Notification of Ethics Clearance to Conduct Research with Human Participants

---

Principal Investigator: Kerstin Dautenhahn (Electrical and Computer Engineering)

Collaborator: Melanie Jouaiti (Electrical and Computer Engineering)

Student investigator: Kevin Fan (Electrical and Computer Engineering)

Student investigator: Hamza Mahdi (Electrical and Computer Engineering)

File #: 43723

Title: Shared vs Fusion control: how do different types of collaboration influence enjoyment in a robot-mediated game?

---

The Human Research Ethics Board is pleased to inform you this study has been reviewed and given ethics clearance.

**Initial Approval Date: 11/04/21 (m/d/y)**

University of Waterloo Research Ethics Boards are composed in accordance with, and carry out their functions and operate in a manner consistent with, the institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS, 2nd edition), International Conference on Harmonization: Good Clinical Practice (ICH-GCP), the Ontario Personal Health Information Protection Act (PHIPA), the applicable laws and regulations of the province of Ontario. Both Boards are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (HREB) and IRB00007409 (CREB).

This study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

**Expiry Date: 11/05/22 (m/d/y)**

Multi-year research must be renewed at least once every 12 months unless a more frequent review has otherwise been specified. Studies will only be renewed if the renewal report is received and approved before the expiry date. Failure to submit renewal reports will result in the investigators being notified ethics clearance has been suspended and Research Finance being notified the ethics clearance is no longer valid.

Level of review: Delegated Review

Signed on behalf of the Human Research Ethics Board

Vanessa Buote, Ethics Advisor, vbuote@uwaterloo.ca, 519-888-4567, ext. 30321

This above named study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Documents reviewed and received ethics clearance for use in the study and/or received for information:

file: sop__polar_armband.pdf

file: covid19-field_and_off-campus_work_with_human_participants_safety_plan_template_v.1.0_oct2020.pdf

file: incidental_findings_V1_20211102.docx

file: MyJay Standard Operating Procedure_april_14.pdf

file: Dautenhahn - Interactive Robot (child interactions) - April 6th 2021.pdf

file: XBOX ELITE CONTROLLER EN PT FR ES - US CA LATAM.pdf

file: polar_verity_sense_manual.pdf

file: polar_verity_sense_manual.pdf

file: study_setup_diagram.pdf

file: COVID-19 Self-Assessment.pdf

file: measurements_V2_20211002.pdf

file: Table_distance_participants_V2_20211002.pdf

file: study_flowchart_V1_20211002.pdf

file: Engagement_questionnaire.pdf

file: resting_text.pdf

file: info_for_research_with_children_V3_20211026.pdf

file: Qualtrics_Survey_V3_20211026.pdf

file: assent_research_with_children_Session1_V3_20211026.pdf

file: assent_research_with_children_Session2_V3_20211026.pdf

file: Recruitment_V3_20211026.pdf

file: feedback_letter_V2_20211002.pdf

Approved Protocol Version 3 in Research Ethics System

**This is an official document. Retain for your files.**

**You are responsible for obtaining any additional institutional approvals that might be required to complete this study.**

# Appendix B

# Study 1 Questionnaires

This appendix includes the student's reflection worksheet.

Instructor Name: ______________________
Date: ______________________
Session Time: ______________________

**Student Goal Setting and Reflection**

(Please write the answers for your student and place your completed form in Melissa Sager's mailbox)

**Goal Setting** (beginning of procedure):

What goal will you work on today?

______________________________________________________________

______________________________________________________________

__________________________

How will you do it?

______________________________________________________________

______________________________________________________________

__________________________

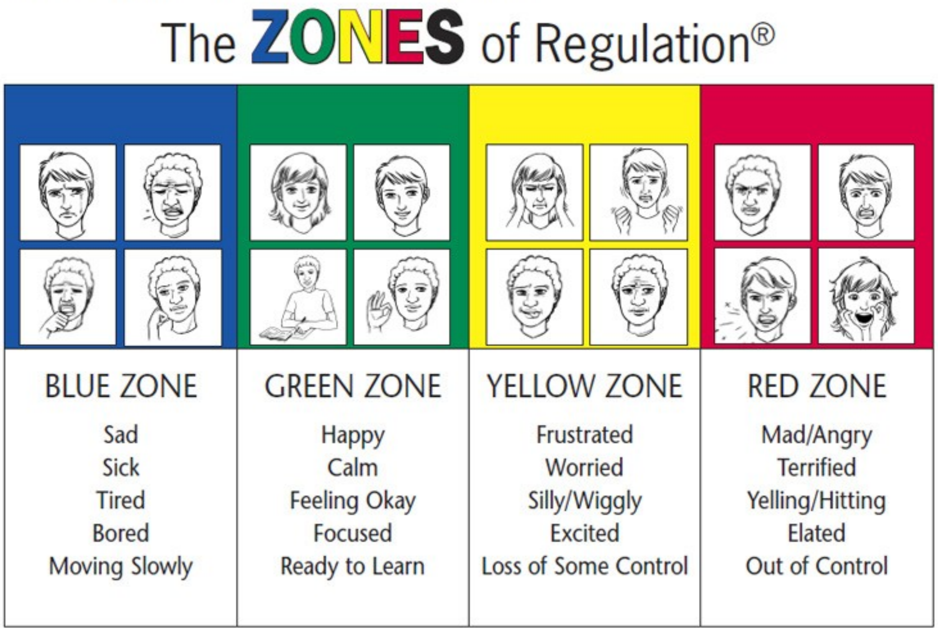
How will you know you reached your goal?

______________________________________________________________

______________________________________________________________

__________________________

What zone are you in (circle one)?




**Goal Reflection** (end of procedure):

Have you reached your goal yet? **Circle one**: Yes / Not Yet

What helped you?

_______________________________________________

_______________________________________________

____________________

What didn't help you?

_______________________________________________

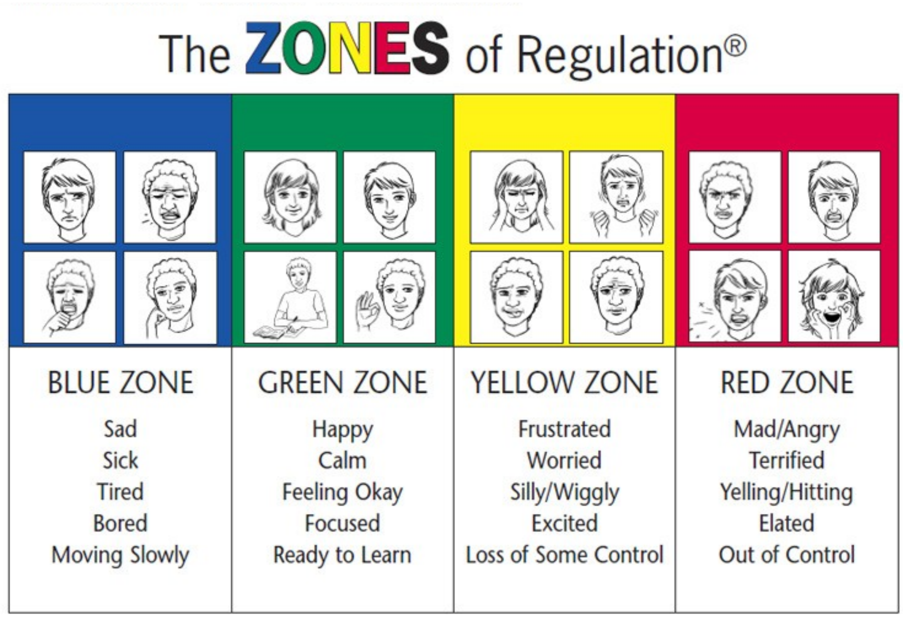
_______________________________________________

____________________

What will you try next time?

______________________________________________________________________
______________________________________________________________________
____________________________

What zone are you in? Circle one:




**Post-session Comments** (to be completed when the student is not present)

Did you set a challenging, yet achievable goal with your student? Please describe:

______________________________________________________________________
______________________________________________________________________
___________________________

Which off-task behaviour(s) did you observe in the session (if applicable)?

______________________________________________

______________________________________________

____________________

Which self-regulation strategy did you try and was it appropriate for your student (if applicable)?

______________________________________________

______________________________________________

____________________

Did you follow the procedure details as outlined? If not, when/why did you go “off script”?

______________________________________________

______________________________________________

___________________

Is there any other feedback you could provide that would be helpful to know for future sessions?

______________________________________________

______________________________________________

____________________

Did QT meet the objectives for the session (only to be answered during the intervention phase)?: Yes / No
Details:

______________________________________________

______________________________________________

____________________

Mark your selection with an “X” (see more details regarding each level of engagement below the table):

| Levels of Engagement | **Engagement**: High Attention + High Commitment | **Strategic Compliance**: High Attention + Low Commitment | **Ritual Compliance**: Low Attention + Low Commitment | **Retreatism**: No Commitment + No Commitment | **Rebellion**: Diverted Attention + No Commitment |
|---|---|---|---|---|---|
| Your student's level of engagement while working on the goal **before** the self-regulation intervention. | | | | | |
| Your student's level of engagement while working on the goal **after** the self-regulation intervention. | | | | | |

**Five Levels of Engagement** (Schlechty 2002)

**Authentic Engagement (High Attention-High Commitment)**

This is the highest level of student engagement. In this level, the student sees that the activity is personally meaningful. They have the will to persist and learn in the face of difficulty. Moreover, the students feel that their goal is to get the activity right and perform well.

**Strategic Compliance (High Attention-Low Commitment)**

The student in this level still sees the value of the work and finds the activity as worthwhile but only because of certain reasons, such as good grades and approval. If the work does not guarantee them these extrinsic returns, they will abandon it. Students in this level are also committed to their work primarily due to teacher recognition and peer appreciation.

**Ritual Compliance (Low Attention-No Commitment)**

This is the level where students set learning at a low level and are working only for the sake of compliance or obedience. They do the work only to avoid negative consequences.

**Retreatism (No Attention-No Commitment)**

The students is **DISENGAGED** with the task and activity and are emotionally withdrawn. They do not participate in the task and feel unable to do what is asked and expected of them. Furthermore, the students think they cannot do the activity because of poor capability and of lack of sense of activity relevance.

**Rebellion (Diverted Attention-No Commitment)**

The student is **DISENGAGED**; refuses to do the work and/or disruptive. For this level, students develop a negative attitude and poor work.

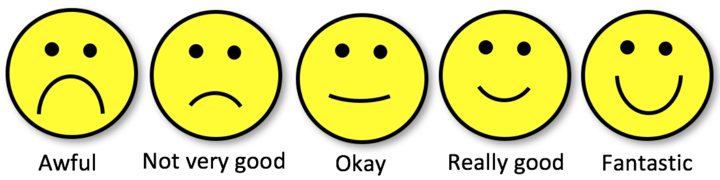
# Appendix C

# Study 2 Questionnaire

The first item is the student's questionnaire and the second one is the student's reflection worksheet.

<u>Questionnaire for Students</u>

1) How much did you enjoy having the robot in our class?




2) How many stars would you give to the robot for its friendliness? (The more stars the friendlier)

★ ☐

★ ★ ☐

★ ★ ★ ☐

★ ★ ★ ★ ☐

★ ★ ★ ★ ★ ☐

3) How many stars would you give the robot for its intelligence?
(the more stars the more intelligent)

- ★ ☐
- ★ ★ ☐
- ★ ★ ★ ☐
- ★ ★ ★ ★ ☐
- ★ ★ ★ ★ ★ ☐

4) Do you think the robot helped you during the session?
- Yes ☐
- Maybe ☐
- No ☐
- I do not know ☐

5) Would you like to have the robot in your future classes?
- Yes ☐
- Maybe ☐
- No ☐
- I do not know ☐

If you answer “Yes” or “Maybe”, how often?

- Never ☐
- Rarely ☐
- Sometimes ☐
- Often ☐
- Always ☐

6) I think of the robot in my classes as a……

- Classmate ☐
- Friend ☐
- Sibling ☐
- Relative ☐
- Stranger ☐
- Parent ☐
- Teacher/Instructor ☐
- Helper ☐
- None of the above ☐
- Other: please tell us what you think:

  ____________________

REB: _________

**QT Study Session Form**

Instructor name: ___________________________ Session Date and Time: ____________________________

*Please complete both sides of the form and place completed form in Mike Gray’s mailbox*

☐ ________________________ has given assent to participate in the study today.
*<Print Student’s Name>*

**1) Goal Setting** (beginning of procedure):

**Work with student to determine their goal for the session. Record the goal below:**

**Work with student to determine how they will know if their goal is met. Record below:**

**Ask student to identify what zone they are in:**

**2) Goal Reflection** (end of procedure):

**Did the student reach their goal?** Yes / Not yet

**If yes, what helped the student to achieve their goal? Record student answer below:**

**If no, what might have helped? Record student answer below:**

**Ask student to identify what zone they are in:**

August 12, 2021

REB: _________

Post-session Instructor Reflection Form (to be completed when the student is not present)

**Did you follow the procedure details as outlined? If not, when/why did you go "off script"?**

**Reflecting on the goal set with the student, was it both challenging and achievable?**

- ☐ Yes: both challenging and achievable
- ☐ No: too challenging
- ☐ No: not challenging enough
- ☐ Other: Please describe:

**How engaged was your student with you during the session?**

| | | | | |
|---|---|---|---|---|
| Very Distracted | Distracted | Neutral | Engaged | Very Engaged |

**Which (if any) off-task behaviour(s) did you observe in the session? (check all that apply)?**

- ☐ Shutting down/upset/anxious/withdrawn
- ☐ Lethargic/tired/bored/inattentive
- ☐ Off topic conversation/questions/silly
- ☐ Emotional outbursts
- ☐ Energetic/Fidgeting/Distractable/Restless
- ☐ Negotiating
- ☐ Daydreaming
- ☐ Other: please describe

**If applicable, which self-regulation strategy did you try (check all that apply).**

- ☐ Breathing exercises
- ☐ Brain breaks
- ☐ Movement breaks
- ☐ Mindfulness breaks
- ☐ Positive talk
- ☐ Self-monitoring (e.g. timer)
- ☐ Other (list all used) ____________________________________________________________

**If used, was the self-regulation strategy successful for your student**? Yes ☐ No ☐

**Is there any other feedback or information you could provide about the session?**

August 12, 2021