PLAYFULNESS IN CHILDREN WITH SEVERE CEREBRAL PALSY WHEN USING A ROBOT

by

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Abstract

Free play is not only one of the most important means through which children develop and know their world, but also it is the way in which they show their physical, cognitive, social and creative abilities. Children with severe physical disabilities have motor control problems that affect gross and fine motor skills, and in turn, manipulation. Without manipulation, children's play is less effective for exploring. Thus, it is much more difficult for these children to learn and to develop because they cannot interact easily with the environment. Generally, they are observers of other's play rather than active participants in play. Consequently, the children's development is delayed.

This study investigated the effect of a robot-based intervention on 1) child's playfulness; 2) mother's directiveness, responsiveness, and affect/animation; and 3) child's play performance and satisfaction with their play. The family's satisfaction with the robotic intervention was determined.

The study's protocol was tested in a pilot study with a child with cerebral palsy and her mother followed by a partially non-concurrent multiple baseline design with four children with cerebral palsy and their mothers. All children were level IV or V in both the Gross Motor Classification System and the Manual Ability Classification System. The intervention was the availability of a Lego robot during free play at home. Playfulness was measured through the Test of Playfulness version 4, play performance was measured through the Canadian Occupational Performance Measure, and the maternal interactive behavior Maternal Behavior Rating Scale revised.

The total length of the study was different for each mother-child dyad with the majority participating about 14 weeks with two sessions per week. Each session was 15 minutes long. The study had three phases; a baseline (5-8 sessions), an intervention (10 sessions) and a one month follow-up (three sessions). During the entire study children played with their mothers at home with their own toys. During the baseline and the follow-up phases the child and mother played without the robot. The robot was available to the mother and child in the free play sessions only during the intervention phase. Children were trained in the use of the switches in order to make the robot move and carry objects according to a protocol before starting the intervention phase.

According to the standards for assessing the levels of evidence for single case design, the main findings of this study provided strong evidence that the robotic-based intervention increased playfulness in children with severe motor impairment due to cerebral palsy; moderate evidence that it decreased mother's directiveness; and no evidence that it increased mothers' responsiveness during the intervention. The robotic intervention improved the mothers' perception about their children's play performance and increased their satisfaction with their children's play performance. Future research may be oriented towards improving the level of evidence provided by the present study; exploring the impact of robots in other aspects of the play experience of children with CP such as pretend play and play with peers; and comparing traditional interventions for improving mother-child interaction with robotic interventions.

Preface

This thesis is an original work by Adriana María Ríos Rincón. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "THE EFFECT OF A ROBOTIC INTERVENTION ON THE FREE PLAY EXPERIENCE OF CHILDREN WITH SEVERE CEREBRAL PALSY", No. Pro00033318, September 11, 2012. This thesis also received ethics approval from the University of Alberta Research Ethics Board for the administrative amendments Pro00033318_AME2, March 28, 2013; and Pro00033318_AME3, May 9, 2013.

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I was responsible for the data collection and analysis as well as the writing of the manuscript. K. Adams, J. Magill-Evans, and A. M. Cook contributed to manuscript edits.

Dedication

To my patients with cerebral palsy who inspired me to find a way to allow them to play.

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1. INTRODUCTION

Free play is not only one of the most important means through which children develop and know their world, but also it is the way in which they show their physical, cognitive, social and creative abilities (Knox, 2008). Children with severe physical disabilities have motor control problems that affect gross and fine motor skills, and in turn, manipulation. Without manipulation, children's play is less effective for exploring. Thus, it is much more difficult for these children to learn and to develop because they are not able interact easily with the environment. Generally, they are observers of other's play rather than active participants in play. Consequently, the children's development is delayed.

This chapter starts with the definition of play and theories related to play. It is followed by a discussion of children free play and playfulness, play of children with cerebral palsy, and assistive technology as a strategy for children with cerebral palsy to access free play. Maternal interactive behavior is addressed next, followed by the conceptual elements that support this research. The significance of the research is covered. The chapter ends with the research hypotheses and questions

1.1. Play Theories

Play is a crucial part of life that has been commonly associated with freedom, pleasure and enjoyment (Bundy, 1993; Huizinga, 1955; Sutton-Smith, 2001). Contemporary literature in this field states that play and leisure are resources for transcending negative life experiences and contributing to the capacity to cope with stress, increase self-concept and self-esteem, and enhance social competence (Blanche, 2008).

Play has been described as a complex construct by scholars who have tried to define it, but a complete consensus as to its definition has not been reached (Ferland, 2005; Parham, 2008). Contemporary play theories emerged around the early twentieth century and can be classified into biological, psychodynamic, cognitive or sociocultural theories (Parham, 2008). The biological perspective of play is generally related to the theories of optimal arousal, meaning play is considered as one of the ways through which the brains of many species are enhanced and enriched by the playful exploration of the environment (Burghardt, 2005). The psychodynamic theory of play was constructed principally by Freud who was interested in play as a means through which children project their unconscious desires and conflicts. The psychodynamic theory explains play as a way for the child to connect their internal (conflicts, desires) and external (reality) worlds (Reilly, 1974).

Regarding cognitive developmental theories, Piaget did not develop a play specific theory, but his theory of cognitive development significantly influenced our understanding of play. He is one of the most cited authors in the field of children's play and his most important contribution was to state that play is one of the means by which children develop symbols (Piaget, 1951). Sociocultural theories state that play is crucial for social life and culture. Some theories in this category state that play is influenced by culture with play behaviors of human beings built on culture (Fleer, 2010; Huizinga, 1955). The play theory of Sutton-Smith (2001) integrates elements of cognitive theories and socio cultural theories of play. For children, he states that play is a means for creative problem solving. His point of view is opposite to Piaget's statement that before playing, the child understands a problem through accommodation, while Sutton-Smith (2001) stated that innovative problem solving occurs during play. Sutton-Smith points out that a child can learn and develop through different ways such as following instructions, being trained by adults, or playing. When children play freely they are learning by creative problem solving.

As part of his play theory, Sutton-Smith (2001) recognizes that the concept of play has lots of ambiguity and that there are gaps between the different disciplines that developed play theories. His proposed solution to this ambiguity was to identify seven rhetorics of play from the theory. Rhetorics are "large-scale cultural ways of thought in which most of us participate in one way or another" (Sutton-Smith, 2001, p. 8). These rhetorics include the diverse points of view in which play has been explained and that help to understand the overall character of the play theory. The first five rhetorics are not directly related with children's play.

1) *play as fate* is related to the magic component implicit in the play experiences of human beings. Play is related to destiny, luck, gambling and astrology.

2) *play as power* explains the play from the point of view of sports, athletics and contests.

3) *play as identity* is related to cultural events such as festivals, community celebrations or traditions. Play is a means to fortify the identity of a community.

4) *play as the imaginary* is related to the human's creative expressions, including literature and children's phantasmagoria.

5) *play as frivolous* is related to activities of the idle or the foolish.

The two rhetorics most related to children's play are *play as progress* and the *rhetoric of the self*. Play as progress explains how children adapt and develop through play. This is the rhetoric most applied to children's play and it commonly supports educational programs. Here, the value of play is in its use to develop children's cognitive or motor skills rather than enjoyment. The rhetoric of play as self-incorporates the elements of enjoyment and fun in play theory. The player chooses to play because playing generates pleasure and enjoyment. Play is valued as an end in itself.

Skard and Bundy (2008) state that in order to determine if an activity is play or nonplay several characteristics must be considered. Bundy (2010) identified the play traits that differentiate play from nonplay. Play is absorbing, and it also involves attention to the process rather than the product, is thought to be fun, and is more surprising than predictable. In addition, during play player go beyond their abilities to meet a challenge, the player is controlling the activity, the player can be whoever she or he wants, objects can be used in untraditional and creative ways, and the rules are created from the "as if" element (pretend) of play.

Even though it is difficult to define play, if a researcher wants to assess play it is necessary to distinguish play from nonplay (Bundy, 1993). It is also necessary to state criteria that must be met to define an activity as play (Burghardt, 2005). Defining play is a crucial step when an intervention or study related to play is being developed. A clear definition of the play behaviour allows it to be detected, analyzed or promoted. This is even more important when play is analyzed in children because a blurred definition can lead to mistakes in the interpretation of children's play. In this study, play is an activity that is intrinsically motivated, process oriented or focused on the processes rather than on the ends, enjoyable, actively engaged and controlled by the player who may suspend some elements of reality as outlined below.

Intrinsically motivated activity: A player plays just because he wants to. There is no external reason for play, just that the player wants to engage in the activity (Harkness & Bundy, 2001). Intrinsic motivation is also known as "autotelic", meaning that the purpose of the play is just the play experience itself (Parham, 2008; Piaget, 1951). The environment can be very inviting for the child to play but the decision to play is totally personal, voluntary and internal.

Process oriented activity: In play, the activity is more oriented to the process than to the final product. The final product is not the most important thing. This allows the player to enjoy the process in which the activity is carried out (Blanche, 2008; Skard & Bundy, 2008).

Enjoyable, fun or pleasurable activity. Play has been associated with positive affect (Burghardt, 2005; Parham, 2008; Skard & Bundy, 2008). Many theories related to play include this characteristic because without pleasure or enjoyment there is no play (Bundy, 1993; Ferland, 2005). This does not mean that the player needs to be smiling if playing; in fact, especially in competitive games, the player can feel some tension because he does not know whether he will win (Huizinga, 1955).

Active engagement and internal control of the player: When the player is actively engaged, he is an active participant in the activity, making decisions about the activity and its design. This characteristic is related to *internal control*, in which the individual feels control over himself and the environment because he is making decisions (Skard & Bundy, 2008). Therefore, when an individual is not engaged in the activity, likely this activity is nonplay because he is only a passive observer of the other's play. Active engagement and internal control means that during play an individual is controlling the activity.

Suspension of reality: This condition is defined by free choice about the amount of suspension of reality by the player (Skard & Bundy, 2008). This characteristic is related to the symbolic component of many types of play in which the player pretends to be another person or even an object during play. This characteristic has been referred to as symbolic and pretend play (McCune-Nicolich, 1981; Piaget, 1951).

1.2. Children's free play and playfulness

The ideal example of play is children's free play. Free play is the kind of play that children engage in naturally without any orientation or direction by a clinician or teacher or parent. In contrast to planned or directed activities, free play occurs when an activity is spontaneous, intrinsically motivated, actively engaged in and self-regulated (Missiuna & Pollock, 1991). Free play has many benefits because it provides children with the opportunity to discover their own capabilities, to try out objects, to make decisions, to comprehend cause-and-effect relationships, to learn, to persist, and to understand consequences (Missiuna & Pollock, 1991).

Skard and Bundy (2008) state that play includes the skills needed to play, play activities and playfulness with playfulness as the main aspect of play. Playfulness has been defined as the disposition to play (Skard & Bundy, 2008) and a style that people use to face problems and situations in a flexible way (Bundy, 1993). This also has been called the ludic attitude underlying the action of play that stimulates children to explore and interact with their environment, imagine and use their sense of humor (Ferland, 2005).

Based in the works of Newman (1974) and Bateson (1971), Skard and Bundy (2008) stated that playfulness has four elements: intrinsic motivation, internal (self) Control, freedom to suspend reality and framing. Playful interactions are intrinsically motivated because any player only takes part in play because she or he wants to. Play is generated by personal motivation. The decision to engage in play is freely made and only taken because the player finds something that may be fun. Playful activities have internal control because the child can "decide what to play, how to play, when the play begins and finishes and who to play with" (Skard & Bundy, 2008, p. 75). These sorts of decisions give children the feeling of control over themselves and their environment. Playful experiences include the freedom to suspend reality because players may pretend that they are something or somebody else while they are playing. The frame of play is related to the communication during play. This includes the messages that the child gives about how others should interact with him or her. It also includes how the child responds to other's cues. Framing is composed of the cues children give to others about how they want to be treated and how children respond to others' cues. The player's contributions to the play transaction are determined by these four elements. Yet, the expression of them is affected by the supportiveness of the environment for play (Skard & Bundy, 2008).

The three first elements are a continuum. This means that it is not possible for an individual to feel completely intrinsically motivated, internally controlled and free to suspend all of the restrictions of reality during play (Bundy, 1993). There are external elements that limit the activity such as availability of toys, safe conditions, external social rules, time restrictions and so on. Bundy explains the three elements of playfulness in a scale according to their weight. The relative weight of these three elements (intrinsic motivation, internal control and freedom to suspend reality) in a balance determines if what the player is doing has more playfulness (free play) or less playfulness (nonplay). The greater the intrinsic motivation, internal control and freedom of suspending reality, the nearer the activity is to play. Also, the greater the extrinsic motivation, external control and constrains for suspending reality, the nearer the activity is to nonplay (Bundy, 1993).

Sutton-Smith (1971) states that playfulness is related to adaptability and creativity. Playfulness has been also related to coping (Saunders, Sayer, & Goodale, 1999) and motivation in children (Reid, 2005). Playful people tend to be more flexible and adaptable than people who are not playful because they can generate several solutions to problems (Harkness & Bundy, 2001). Thus, being playful is more important than practicing any play or leisure activity, because in the absence of playfulness, activities may turn into work (Bundy, 1993).

1.2.1. Play and development

Researchers have explained children's development through play in terms of discovery, learning, mastery, self-esteem, self-concept, adaptation, creativity, self-expression and social skills (Blanche, 2008; Ferland, 2005). Child's development through play occurs in a natural way and it is not necessary to stimulate typically developing children to play. Play is an ideal way to discover the world through practice with different objects and experiences (Ferland, 2005). Through play, children can explore the relationships between their body and the environment using sensory information, gain information about the properties of objects, and develop rules about their own temporal and spatial location (Reilly, 1974).

Self-expression and creativity are also promoted by play. Play is the pure expression of who a person is because it is free (Bundy, 1993); thus, play is a wonderful setting for children to develop and show their personalities. Creativity is related to the freedom to suspend reality element of play. In play, children decide what is real and what can transform according to their desires. The kind of imagination present in pretend play (e.g., inanimate objects treated as animated), is related to the development of creativity, humor and originality in problem solving (Ferland, 2005). A sequential development of play has been described in different developmental dimensions such as cognitive (Piaget, 1951; McCune-Nicolich, 1981), social participation (Brain & Mukherji, 2005) and occupational performance (Knox, 2008).

1.2.2. Social play and object play

Play experience is carried out through interactions. During play children learn about the properties of objects and how to interact with objects and people (Reilly, 1974). Play where the child interacts with people is called *social play*, and play where the child interacts with objects is called *object play*. Both types of play interactions have important benefits for children's development. In social play the child can interact with peers or adults during playful activities. It is an arena for development of social skills such as discussion, negotiation, cooperation, compromise, empathy, altruism and competition (Coplan, Rubin, & Findlay, 2006). Social play also provides the opportunity to deal with negative feelings such as frustration; for example when a playmate takes a toy that a child wants (Ferland, 2005). Interaction with people in social play starts with dyads and progresses to play in groups. The first play interactions occurs with parents and other family members; thus, parent-child interactions influence later social play with peers (Brain & Mukherji, 2005). Parent-child attachment is related to children's later complexity of play skills and positive social engagement (Crockenberg & Leerkes, 2000).

Object play is the playful interaction of the child with objects. Manipulation of objects is a crucial aspect of the human occupational nature (Munier, Teeters, & Pierce, 2008). According to developmental theories, manipulation of objects is crucial for cognitive development. Piaget stated that in the sensory-motor period children interact with objects and this interaction is important for the construction of the child's elaborated levels of thinking, such as abstraction and symbol formation where they manipulate thoughts (Piaget, 1951). Gibson's Ecological approach to perception points out that the active discovery of the physical properties of objects is crucial in children's knowledge about the environment (Gibson & Gibson, 1955). Munier et al. (2008) state that according to the Ecological approach the meaningful physical environment is perceived by the individual in terms of medium, substances, surface and affordances (or opportunities for interaction).

Motivation theories have highlighted the importance of the interaction with objects as well (Munier et al., 2008). Theories from Optimal Arousal explain play as part of the interaction with the environment. Burghardt (2005) presents a complete analysis related to these kinds of theories. Hutt stated (as cited in Burghardt, 2005) that interaction with the environment involves two types of exploration: specific and diversive. In the specific exploration or investigation, the novel object or setting generates in the individual a neutral or negative affect (e.g. anxiety or fear); the behavior is stereotyped and is nonplay. This kind of exploration is present in situations in which the individual explores a new environment in order to know whether there is a potential danger. Diversive exploration generally follows specific exploration. In diversive exploration the individual is motivated by the question: What can be done with the object? The individual is relaxed and has a positive affect because he feels safe and familiar with the object and setting. The behavior is variable or flexible and the experience is playful. The presence of playfulness becomes exploration into the process of play, which has been called object play (Burghardt, 2005). For children's play, the question that drives the exploration is "what can I do with this object or person?" (Coplan, Rubin, & Findlay, 2006, p. 75).

Emotional qualities of the play experience are related to object play. These emotional qualities are sense of competence, mastery, and self-control by the player during the interaction with the environment. Object play is an arena in which children express mastery motivation, competence, and efficacy (Munier et al., 2008). Theoretically, as the sense of self-efficacy increases, the performance of play and satisfaction with the performance increase as well (Reid & Campbell, 2006). Additionally, object play provides children with the sense of control when they decide what to play with and the desire to "see what would happen" as they are playing with an object (Skard & Bundy, 2008).

Csikszentmihalyi's Flow theory (Csikszentmihalyi, 2008) provides support for object play. Flow is a psychological state in which the person feels enjoyment because there is a balance or a good match between a person's skills and the challenges of the environment. The presence of this balance is called the "flow channel" or the "peak experience" (Csikszentmihalyi, 2008). In occupational therapy, this balance has been described by Law (as cited in Emerson, 1998) as a "just-right challenge", which is therapeutic and influences the sense of well-being and satisfaction with performance. Achieving the flow requires certain conditions over the activity. The individual needs to be completely involved in the activity (nothing else matters), and the experience itself is enjoyable. Other conditions are that the individual has the choice to participate, sense of control over the outcome of the activity, sense of the meaningfulness and immediate clear feedback. The active use of a person's skills for a freely chosen goal is the source of enjoyment in a flow experience. When environmental demands exceed the individual skills the state is not in the flow channel but in the anxiety channel. On the other hand, when the individual perceives that his or her skills are higher than environmental demands, channels of apathy and boredom appear (Emerson, 1998). Flow and play share many characteristics. Free play is an expression of the flow state in children due to the fact that children use their skills while engaging in an activity that provides enjoyment. Bundy (2010) states that the Flow theory is related to two elements of playfulness, intrinsic motivation and internal control. Munier et al. (2008, p. 225) stated that "this flow state is easily observed in normal infant object play".

While playing, children have the opportunity to realize the impact that they produce on objects and people; they also develop and practice social and occupational roles when, for example, the child organizes the play (Missiuna & Pollock, 1991). Thus, during free play with objects, children experience a sense of internal control, intrinsic motivation (Bundy, 1993) and mastery (Munier et al., 2008). They also explore, practice skills and feel they cause effects on the environment. This contributes to their development in motor, cognitive and psychosocial dimensions. Free play is the ideal way for children to discover their environment through interaction with objects, people and situations.

Figure 1.1. shows the process that drives development through free play with objects Diversive exploration is a means through which children explore their environment in a playful way, an experience where children have a positive effect. The interaction with objects is called object play. The question that drives this interaction is "What can I do with the object?". The activity is intrinsically motivated because children want to interact with the objects of interest. Since children's motor skills and demands of the physical environment match, children interact with objects into a flow channel that allows children to explore the properties of the object in a playful way (diversive exploration). Thus, children have many opportunities to engage in free play and develop skills. Since the experience is playful, children develop and practice skills through repetition, and children are prepared for a new challenge.

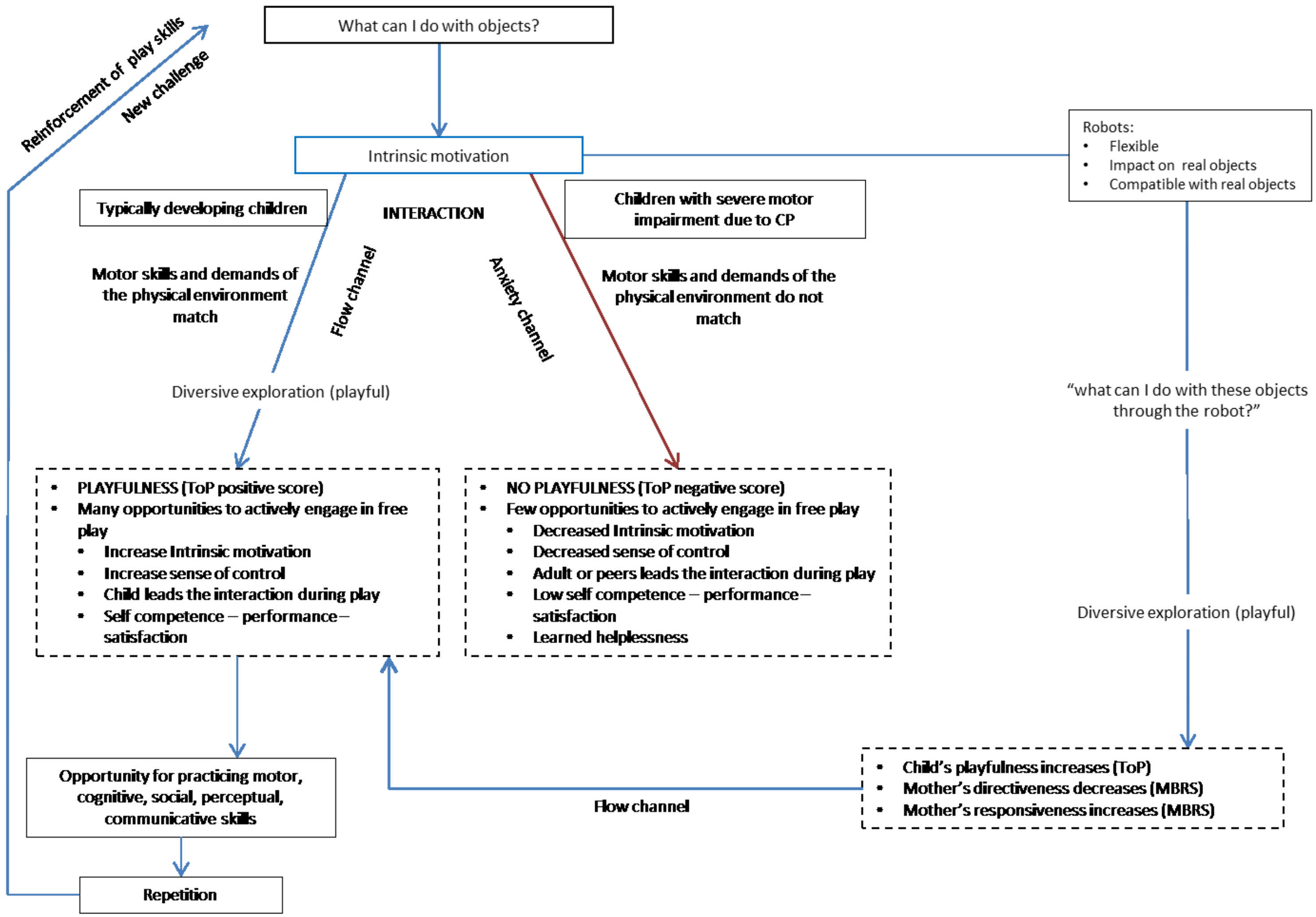


Figure 1.1 Cycle of reinforcement of play and playfulness in typically developing children and children with cerebral palsy without and with Assistive Technology

1.3. Play and Playfulness in children with cerebral palsy

Cerebral palsy (CP) is the most common childhood neurodisability (Eliasson, et al., 2006). CP prevalence in Northern Alberta for extremely premature infants survivors born in the years 2001-2003, was 19 per 1000 live births (Robertson, Watt, & Yasui, 2007). CP affects the child's movement and posture, and, in turn play. CP is a chronic non-progressive disease that affects motor control and appears early in life. It has different levels of severity and variations in clinical motor deficits (Robertson, Watt, & Yucata, 2007). For example, according to the Gross Motor Function Classification System, Expanded and Revised (GMFCS – E & R) (Palisano, Rosenbaum, Bartlett & Livingston, 2008) children with CP in levels IV and V have limitations in head and trunk control and require assistive technology and physical assistance to sit, walk, manipulate, or perform activities of daily living. In contrast, children in Level I can sit with both hands free to manipulate objects, and can walk without limitations (Palisano, Rosenbaum, Bartlett, & Livingston, 2007). In children with severe motor limitations, fine motor skills for manipulation are reduced because of problems in motor control movements that involve head, trunk, arms and hands; thus, children have serious difficulties reaching and grasping objects (Eliasson, et al., 2006). Additionally, some children have communication problems because they may have difficulties producing understandable gestures and vocalizations (Pennington & McConachie, 2001).

Children with CP have limitations that affect engagement in play (Blanche, 2008; Missiuna & Pollock, 1991). The play of children with severe disabilities may be less spontaneous and less internally directed than play in children without disabilities (Hinojosa & Kramer, 2008), and they frequently are unable to communicate when they are finished or bored with an activity. In addition, parents have no clear role in children's play (Brodin, 2005); that is, parents do not clearly know whether play is an opportunity for training the child in specific needed skills, or play is an opportunity for enjoyment (Brodin, 2005).

Missiuna and Pollock (1991) stated that due to the physical impairment, children with CP have a primary deprivation of engaging in free play. This deprivation can generate secondary social, emotional, and psychological disabilities. The child may lack opportunities to interact, and practice skills in order to experience mastery and control of the environment. Children with

CP may be able to engage in play activities despite their physical disability but people around them frequently impose additional constraints (Blanche, 2008). Generally, caregivers and playmates dominate the play so that children with CP become more a spectator of other's play rather than an active player (Blanche, 2008; Brodin, 2005). Children with CP and their families spend more time in activities related to self-care (including rehabilitation) than do typically developing children. This reduces time for family play routines (Brodin, 2005; Hinojosa & Kramer, 2008; Missiuna & Pollock, 1991). With few opportunities for practicing and testing their skills, the children can develop a learned helplessness; that is children assume that they are unable to perform a task by themselves even though they have the required physical abilities (Harkness & Bundy, 2001). All of these situations delay not only child's play and development, but also future functioning in education, community and work contexts (Missiuna & Pollock, 1991).

Playfulness and play skills are affected in children with CP. Infants with CP show less playfulness than infants without CP (Okimoto, Bundy, & Hanzlik, 1999). Children with CP do not actively make decisions during play (Harkness & Bundy, 2001). These decisions are related to what to play, how to play, who to play with and so on. The able-bodied playmates generally lead their play. Thus, children with motor impairment do likely not experience a clear sense of self (internal) control. Children with motor impairments also spend more time distracted during play and their play is less complex than the play of typically developing children (Jennings, Connors, & Stegmann, 1988). Expressing playfulness during free play is affected by children's cognitive-behavioral problems and gross motor function; however, children with limited self-mobility who are more playful are more self-determined than those who are less playful. Children who are self-determined present behaviors oriented towards meeting personal life goals; these behaviors include identifying desires, actively pursuing interests, making decisions, and solving problems (Chang, et al., 2014). The finding that playfulness was an indicator of self-determined behaviors for children with CP with limited self-mobility suggested that those children in gross motor function level III to V who are more playful may be able to find strategies to use assistance, to make choices or solve problems.

Children with severe motor impairments have few opportunities to interact with objects. Consequently, their knowledge about the concrete world (properties of objects and physical environment) is limited and they are delayed in reaching abstract levels of play (i.e. symbolic play) (Ferland, 2005). Symbolic play is a cognitive skill that requires abstraction in terms of using an object as something else, attributing absent properties to objects, and assigning absent objects or actions to the present objects (Stagnitti, 2007 as cited in Pfeifer, Pacciulio, Dos Santos, & Dos santos, 2011). Children with CP can show the same play behaviors as typically developing children but these play behaviors appear late in their development (Gowen, Jonhson-Martin, Goldman, & Hussey, 1992). In fact, due to their physical limitations, they have constraints in showing their pretend play (Pfeifer et al., 2011) and object play (Gowen et al., 1992).

Children with CP feel that their limitations have affected their opportunities and type of play experience, and they have felt excluded from play activities by their able-bodied peers (Miller & Reid, 2003). In addition, children with severe motor impairment have low levels of participation in recreational, active physical and self-improvement activities (King, et al., 2013).One of the main play and leisure activities of children and adolescents with CP is watching television (Howard, 1996) and their interest in fine motor activities decreases as they grow up (Ferland, 2005). Children with CP are more playful at home than in other familiar settings (schools and community) (Rigby & Gaik, 2007).

Similarly to typically developing children, children with CP want to explore their environment and also ask the question, “What can I do with the object?”, but the interaction with objects fails because their motor skills do not match the challenge of the objects (see Figure 1.1). They cannot effectively manipulate the object in the way they want. This interaction with the objects is carried out in an anxiety channel rather than in a flow channel, because the children’s skills and the environment challenges are not balanced. Consequently, children with CP with severe motor impairments seldom engage in a totally absorbed activity and the interaction with objects is not playful. They have few opportunities to engage in free play and experience mastery, intrinsic motivation, self-control, competence and satisfaction with the performance (Harkness & Bundy, 2001, Jennings et at., 1988; Reid, 2002). This can play a role for children with severe motor impairment in developing a learned helplessness assuming that they are unable to perform a task by themselves although they have the required physical abilities to do it (Harkness & Bundy, 2001).

Promoting play is part of the rehabilitation goals for children with CP. According to Blanche (2008), play has three roles in the rehabilitation of children with physical or cognitive impairment. The first role is play as an important occupation that promotes learning and adaptation. When children engage in free play, they test and practice their skills, which promotes development. Under this role of play, the clinician can assess the child's developmental skills through play. The second role is play as motivator for children to participate in the treatment sessions. The therapist designs activities to achieve therapeutic goals with the child through a playful interaction. Play is a medium for the intervention in which a therapist allows the child to choose some elements of the activity. The first two roles of play have been traditional in rehabilitation for children with CP. They are focused only on the acquisition of functional skills, and fail to explore completely the inherent value of play.

The third role is play as an end in itself. The treatment goal under this role of play is to incorporate play into the child's life. Interventions provide tools to the child and family to increase the quality and frequency of the play experience in the child's daily living routines. According to Blanche (2008,) when the interaction with a child with CP is approached from the third role of play, "doing with" the child rather than "doing to" the child provides more opportunities for expression, exploration and discovery. The interventions have to involve the child's family (Blanche, 2008; Brodin, 2005; Ferland, 2005; Hinojosa & Kramer, 2008). Offering rehabilitation services in the child's natural environment is becoming more common so that the child with CP can develop skills in their normal (Chiarello & Palisano, 1998). Intervention focused in the child's contexts may include modifying tasks, materials, tools and physical characteristics of the environment; providing assistive technology; and educating or instructing the child's family (Law, et al., 2011).

1.3.1. Summary and gaps

In general, researchers have proposed that play has to be included in the lives of children with physical disability. Within interventions, the child is enabled to control his or her environment with improvements in the play experience. Therefore, children with physical disabilities need tools in order for them to have more control of their environment and to experience free play. This in turn will impact children's quality of life, because play and leisure provide wellness to the children's life (Shikako-Thomas, et al., 2012).

Most of the research in play for children with CP has described performance skills (perceptual, motor, cognitive, social) that children use to play (Munier et al., 2008) and the effect of play-oriented intervention on functional outcomes. Few studies have investigated free play and playfulness in children with CP as an outcome. Recent research has investigated the role of playfulness as a determinant of self-determined behaviors in children with CP. Although the need for interventions focused on promoting play in children with CP has been widely stated (Blanche, 2008; Ferland, 2005; Missiuna & Pollock, 1991; Pfeifer et al., 2011), among the studies reviewed, only one investigation assessed the impact of an intervention focused on improving mother-child interaction (Hanzlik, 1989) during play interactions. As a result of this intervention the infant's playfulness increased (Okimoto et al., 1999). Researchers have proposed that play has to be included in the lives of children with physical disability and in those interventions where the child is enabled to control his or her environment, the play experience may improve (Gowen et al., 1992). However, no study has investigated interventions that enable children to play.

1.4. Robots as Assistive Technology for Play

Assistive technology (AT) is a broad term referring to devices, services, strategies and practices used to improve functional capacity of people with disabilities (Cook & Polgar, 2008). The Public Law (PL) 108-364 the Assistive Technology Act of 1998, as amended (2004) defines assistive technology as (as cited in Cook & Polgar, 2008, p.5): "Any item, piece of equipment or product system whether acquired commercially off the shelf, modified, or customized that is used to increase, maintain or improve functional capabilities of individuals with disabilities."

The use of AT for play in children's homes is an important strategy to promote play at home, because the family can interact with the child with assistive technology devices that facilitate play interactions (Lane & Mistrett, 2002). Assistive technology can enable children with disabilities to engage in play either independently or with playmates. It can also allow adolescents to participate in alternative forms of leisure that facilitate competition, team work, and socialization with peers (Crosetto & Swinth, 2008).

AT for children with CP includes devices that can provide assistance for the motor outputs that are commonly affected by a physical disability: mobility, communication and manipulation (Cook & Polgar, 2008). The Let's Play model provides six categories of assistive technologies (Lane & Mistrett, 2002): 1) AT positioning items, 2) mobility items to explore the environment, 3) communication AT items, 4) computer hardware and software, 5) adapted commercial toys, and 6) switches for adapted battery-operated toys.

Positioning equipment helps the child who does not have motor control of head and trunk to change and maintain different positions including sitting, semi reclining, standing, side-lying and prone. The quality of play is influenced by the child's position (Lane & Mistrett, 2002). When children with CP have enough and adequate body support, they are more functional in manual activities (Myhr & Von Wendt, 1991) and in their performance in play and self-care activities (Rigby, Ryan, & Campbell, 2009).

Mobility items are AT devices that encourage and support children with physical impairments to move for exploring their environments. These devices include low-tech AT devices such as walkers, and rocking and ride-on toys (Lane & Mistrett, 2002). They also include high-tech solutions such as powered mobility devices. Powered mobility devices provide children with disabilities the opportunity to explore their environment by themselves with an important impact on perception and on cognition, along with reduced learned helplessness, improved psycho-social development, increased social and symbolic play, and increased confidence and social participation with their peers (Arva, et al., 2008). Power mobility has an impact on some important aspects of the play experience if children with CP (Guerette, Furumasu, & Tefft, 2013) but does not have an impact on the child's object play, which is critical for development.

Another strategy has been to design accessible play equipment and environments for children with disabilities to access play activities in community settings such as playgrounds. This strategy is based on the principles of universal design, which is designing environments and products that can be easily used for all people regardless of user's body size or abilities (Cook & Polgar, 2008). Playgrounds with ramps and wide paths allow children who use wheelchairs and walking aids to enjoy outdoor play (Doctoroff, 2001).

Children who have communication problems generally need augmentative and alternative communication systems (AAC) to enhance their ability to communicate with others; e.g., speech-generating devices (SGD) which are high tech devices for communication (Cook & Polgar, 2008). AAC has been used in promoting symbolic play in children with CP. It has also increased children’s communication and participation with peers and family members (Pashen & Robinson, 2011).

Computer hardware and software can increase play and leisure by providing simulations of experiences that children cannot have in real life. Additionally, computer software provides a broad variety of play scenarios that give the child the opportunity to interact with typically developing children in play activities (Crosetto & Swinth, 2008). Virtual reality is another type of technology used to increase play in children with CP by introducing children into immersive environments (Reid, 2002, 2004; Reid & Campbell, 2006). Computers give children with disabilities the opportunity to engage in play; however, the type of play is not the same as that performed with real objects (Cook, Howery, Gu, & Meng, 2000).

Children with physical impairments like to play with their own toys (Howard, 1996) but their problems in manipulation limit this play experience. Assistive technology for manipulation offers children an alternative way to explore and interact with their environment (Cook, Encarnação, & Adams, 2010). Adapting toys using low-tech elements such as Velcro, foam, and non-slip materials can help to extend, attach, stabilize and confine toys so that the child can interact with toys in an easier way (Lane & Mistrett, 2002). It includes low-tech toy adaptations, and switches for adapted battery-operated toys, and environmental control systems for play in specific tasks, e.g., using switches to control a tape player to listen to a favorite song (Crosetto & Swinth, 2008).

Switch-activated toys are appropriate for young children with CP who enjoy functional play that is characterized by repetition (Lane & Mistrett, 2002). These kinds of devices could be very helpful for children under two years old. For older children, this kind of technology is repetitious and becomes boring after a few repetitions with limited opportunities for creativity (Crosetto & Swinth, 2008). Hsieh (2012) investigated the influence of adaptive pretend play toys on affective expression and imagination in children with CP who had moderate to severe fine motor limitations. The study used semi-structured activities where children followed a play script. The adapted play and toys improved the pretend play of the children.

AT for manipulation includes high-tech devices such as robots. Robots have been used in rehabilitation in different ways: as support in therapeutic activities, as personal assistants, for social integration, and to promote exploration, learning and engagement in play in children with disabilities. A robot is a manipulator that can be programmed to move in different axes and that can be mobile or stationary (Cook et al., 2010). The term augmentative manipulation refers to robots when used by individuals with severe motor impairments (Cook & Cavalier, 1999). Just as mobility by using a power wheelchair is different from mobility by walking, or speaking by using an SGD is different from speaking using one's anatomical structures for phonation, manipulating objects via robots is different than manipulating objects directly using one's own hands. Manipulating objects by using robots demands cognitive skills to understand the relationship between the controls and the robot, and perceptual and spatial skills to understand how the robot moves in relation to the child's body (Poletz, Encarnação, Adams, & Cook, 2010). Among the assistive technologies intended for play with objects, robots are more flexible in interactions with the environment because they can do more than one repetitive action, they can manipulate three dimensional objects in the real word, and they are safe in the interaction with children (Cook et al., 2010). Table 1.1 displays the principal characteristics of studies investigating robots for children with CP.

Robots have the potential to help children with CP engage in object play. They are more flexible and versatile than adapted switch toys and environmental control systems (Cook, Meng, Gu, & Howery, 2002). Children with motor impairments have used robots as manipulators of play materials that generally are part of typically developing children's play (e.g. macaroni box, Lego bricks). The research has used tasks broken into a sequence of programmed movements that the child can activate by using one or more switches (Cook, Bentz, Harbottle, Lynch, & Miller, 2005; Cook et al., 2000; Cook et al., 2002; Kronreif, Kornfeld, Prazac, Mina, & Fürst, 2007; Kronreif, et al., 2005) . Robots have the potential to help children with motor impairments exhibit their cognitive skills when this was not possible with traditional assessment tools (Cook, Adams, Volden, Harbottle, & Harbottle, 2011; Cook et al., 2005). In the same way, when children with motor impairment have interacted with robots, their teachers and parents have positively changed their perception about children's competence (Cook et al., 2011).

Table 1.1 Studies related to robot assisted play for children with CP

Reference	Type of robot used (1)	Type of study	Type of activity	Playmate	Outcome
Cook, Hoseit, Liu, Lee and Zenteno (1988)	MiniMover-5 robotic arm (Microbot, Inc.) and the Apple IIe microcomputer	Case Study	Structured	Researcher	Association of the switch activation with the robotic arm movement
Cook and Cavalier (1999)	MiniMover-5 robotic arm (Microbot, Inc.) and the Apple IIe microcomputer	Case study	Semi-structured	Researcher	Object-related concepts and active initiations of interactions
Cook, Howery, Gu and Meng (2000)	CRS A465	Case study	Structured tasks	Researcher	Description of robot system's performance and child's performance and interactive behavior during the tasks
Cook, Meng, Gu, and Howery (2002)	CRS A465 with an Otto Bock myoelectric prosthetic integrated for the gripper system	Case study	Structured tasks	Researcher	Description of child's and robot system's performance during the tasks
Prazak, Kronreif, Hochgatterer and Fuŕt (2004)	The first prototype PlayROB	Case study	Semi-structured	Nobody (Solitary play)	Use of the robot by children
Kronreif, Prazak, Mina, Kornfeld, Meindl and Füsrt (2005)	PlayROB	Case study	Semi-structured play.	Nobody (Solitary play)	Use of the robot by children
Cook, Bentz, Harbottle, Lynch, and Miller (2005)	Rhino XR-4	Pre-test post-test	Structured	Researcher	• Goal Attainment Scale (operational competence with the robot, functional skills and carryover to the classroom). • Behavioral measures: Auditory and visual prompts, errors in the order of switches activations, look (around/task/instructor) • Teacher's perceptions

Reference	Type of robot used (1)	Type of study	Type of activity	Playmate	Outcome
Schulmeister, Wiberg, Adams, Harbottle, & Cook (2006)	Lego Invention "roverbot" vehicle and robotic arm	Case study	Structured	Researcher	• Child's performance: Number of prompts, location of eye gaze, number of switch errors, time to hit the switches • Child's non-verbal communicative behaviors • Child's teacher perception about changes in the child
Kronreif, Kornfeld, Prazac, Mina, & Fürst (2007)	PlayROB	Case study	Semi-structured	Nobody (Solitary play)	Children's performance during the interaction with the robot
Corrigan, Adams, & Cook (2007)	Lego Invention "roverbot" vehicle and robotic arm	Descriptive	N/A	N/A	Assessment of a platform integration of communication and commands for the robot
Cook, Adams, & Harbottle (2007)	Lego Invention "roverbot" vehicle and robotic arm	Case study	Semi-structured	Researcher	Description of the child's gains
Poletz, Encarnação, Adams, & Cook (2010)	Lego Invention "roverbot" vehicle	Descriptive	Structured	Researcher	Cognitive skills for using the robot
Cook, Adams, Volden, Harbottle, & Harbottle (2011)	Lego Invention "roverbot" vehicle	Case study	Semi-structured	Researcher	Cognitive skills for using the robot
Klein, Gelderblom, de Witte and Vanstipelen (2011)	IROMEC	Single case ABAB	Structured	Occupational Therapist	• Playfulness increased in two out of three children. • IROMEC questionnaire increased in two children, while gradually decreased in one child. • Therapists perceived a limited match between the children's needs and the characteristics of the robot as a toy.
Encarnção, Piedade, Adams, & Cook (2012)	Lego Invention "roverbot" vehicle and Virtual robot	Descriptive	Structured	Researcher	Cognitive skills for using both robots
Cook A. , Encarnação, Adams, Alvarez, & Rios (2012)	Lego Invention "roverbot" vehicle and Virtual robot	Descriptive	Structured	Researcher	Cognitive skills for using both robots
Encarnação, P; Alvarez, L; Rios, A; Maya, C; Adams, K; Cook, A (2014)	Lego Invention "roverbot" vehicle and Virtual robot	Descriptive	Structured	Researcher	Cognitive skills for using both robots

Reference	Type of robot used (1)	Type of study	Type of activity	Playmate	Outcome
Besio, Carnesecchi and Converti (2013)	IROMEC	Pre-test Post-test	Structured (IROMEC Play scenarios)	Occupational Therapist	Prompts for understanding how to play decreased in the last session while prompts for playfulness remained the same in both sessions.
Rios; Adams, Magill-Evans, and Cook (2013) (2)	Lego Invention "roverbot" vehicle	Single case AB	Free play	Mother	Playfulness level increased slightly during the intervention. Child did not interact with the robot the whole sessions

Notes:

(1) Description of the robots from the references:

<u>Robotics manipulators: (full sentences are not needed in notes to a table- I modified one as an example)</u>

- The MiniMover-5 robotic arm (Microbot, Inc.) is an anthropomorphic robotic arm which size is about half adult human arm. It has a base, an upper arm, a forearm and a two-fingered gripper. This is a stationary robot.
- The CRS A465 is robotic arm approximately the same size as an adult human arm, can rotate about its base, flex and extend at the elbow and shoulder, extend, flex, supinate, and pronate at the wrist, and open and close the gripper. This is an stationary robot.
- The PlayROB is a 3DOF (degrees-of-freedom) Cartesian configuration robot with a special gripper for grasping and inserting Lego bricks on a playground made on Lego bricks as well. This is an stationary robot.
- The Rhino XR-4 is a five-degree-of-freedom robot arm that moves similarly as the human arm moves. The robot can rotate around its base, bend at the shoulder, elbow and wrist, and rotate at the wrist. It also opens and close its two-fingered gripper. This is a stationary robot.
- IROMEC is a modular and configurable robotic platform that is a mix of humanoid and vehicle like, depending on its horizontal or vertical position.

<u>Lego Inventions:</u>

- Robots made of Lego pieces. The "roverbot" vehicle looks like a truckand is mobile; "robotic arm"is stationary with a base, an upper arm, a forearm and a gripper. Both are portable.

(2) Rios; Adams, Magill-Evans, and Cook (2013) is the pilot study part of the present dissertation.

Robots also have shown potential to support adult-child interactions in which the researcher is more conversational and less directive while children with motor impairment interact with a robot (Cook et al., 2000). Other researchers have developed "robot-supported" play scenarios in laboratory studies where the robot has the role of a social mediator in the interaction of children with disabilities (motor impairment, cognitive impairment, and autism) and their environment during structured therapeutic and educative activities (Besio, Caprino, & Laudanna, 2008; Robins, et al., 2012).

A type of robot used in research is the Lego robots. Lego Invention robots are a low cost reliable type of robots that have been used in educational and research settings with children with and without disabilities. This type of robots is an alternative to traditional testing that can be used for estimating cognitive skills in children with severe motor impairments (Encarnaçao, et al., 2013; Poletz et al., 2010). Additionally, experts in assistive technology including an adult with a motor impairment, judged Lego robots as having potential for spontaneous play and communication (Corrigan, Adams, & Cook, 2007). Children have fun using Lego robots and increase their sense of independence. For example, they prefer to do things using the robot rather than directing another person (Cook et al., 2010). Children with severe motor impairments can operate Lego robots. These robots are also portable, appealing to children and affordable. These characteristics make it possible to consider them for long-term use by parents and teachers at home or schools (Cook et al., 2010).

It is possible that robots have the potential to help children with CP express their playfulness during free play. Enjoyment, curiosity and active engagement, elements of playfulness, have been observed while children interacted with robots such as (Cook, Hoseit, Liu, Lee, & Zenteno, 1988; Cook, et al., 2000). Two robotic studies have measured play or playfulness as an outcome. Klein, Gelderblom, de Witte and Vanstipelen (2011) found changes in playfulness (measured through the ToP) in two out of three children with developmental disabilities during an occupational therapy intervention using a robot named IROMEC. Therapists perceived a limited match between the children's needs and the characteristics of the robot as a toy. Besio et al. (2013) investigated the type and frequency of prompting provided by therapists during some robotics sessions with four children with CP. The robot used in the study was the IROMEC and the activities were structured using play scenarios developed previously (Robins, et al., 2012). Results revealed positive changes in prompts for understanding how to play while prompts for playfulness remained the same in the first and the last sessions. The authors concluded that IROMEC showed little added value for children with CP during occupational therapy sessions due to a limited matching between children's needs and robot's characteristics. They also observed that therapists tried to enrich the predefined IROMEC play scenarios by inventing novel play situations where children had to make the robot reach different objects in the room.

1.4.1. Summary and gaps

Robots have the potential to help children with CP engage in play with objects Children with severe motor impairment can demonstrate cognitive skills by using robots, and they can also learn how to operate the three switch interface (Cook et al., 2010). Typically developing five-year old children can reach the fourth cognitive level needed to operate the robot using three switches (Cook, Adams, Encarnação, & Alvarez, 2012). A four-year- old child with CP and a cognitive age equivalent less than three years old had difficulties and low interest in playing with the robot using switches (Rios Rincon, Adams, Magill-Evans, & Cook, 2013). Children's success in the understanding of the use of a robot has depended on the flexibility of the robotic system, not only in terms of the degrees of freedom but also related to the capacity of the robotic system to be adjusted to different levels of cognitive demands for the child. In studies where the task was too rigid and too challenging, or the interface was too complicated, children had problems understanding how to operate the robot and became passive, frustrated and uninterested (Kronreif et al., 2007). The placement of the switches for children with severe motor impairments has been challenging. Researchers also have found that a training period is necessary for the child to understand how to operate the robot.

Among the studies summarized in Table 1.1, two were pre-test post-test design (Besio, et al., 2013; Cook, Bentz, Harbottle, Lynch, & Miller, 2005) and two used a single case design (Klein, et al., 2011; Rios Rincon, et al., 2013). The rest were case studies or descriptive research. Most of the studies used semi-structured or structured activities. In the structured activities the goal of the activity was defined by researchers and the child was not expected to modify any element of the activity. These studies were more skills-oriented rather than play-oriented. Generally the outcomes have been developmental processes such as performance in the use of the robot, communication or cognitive skills rather than play. Play was used as a modality or medium of interaction between the researcher and the participant. Even though the interactions with the robot were labeled as play, they were adult-oriented activities where the researcher pre-established a goal (e.g., play scripts or play scenarios).

Based on play theory, children's play is related to the enjoyment of using one's own skills during free choice activities rather than following others' instructions for performing a targeted activity. When the activity was structured (i.e., following a play script), therapists tended to abandon the script and invent novel play situations for children (Besio, et al., 2013). In the studies that used semi-structured activities, researchers allowed children to incorporate some elements into the original target behavior and these studies were more play-oriented. Three studies measured play as the outcome variable including a pilot study that is part of the present dissertation (Besio, et al., 2013; Klein, et al., 2011; Rios Rincon, et al., 2013). These studies have been single case pilot studies that do not provide evidence of the impact of robots on the playfulness of children with CP. Research that measured outcomes other than play provide valuable information about the cognitive, perceptual and physical skills required for operating a robotic system, as well as the impact of robotic intervention during play activities on other dimensions of children's development.

In the summarized studies the playmates were the researchers, occupational therapists or there was no playmate (see Table 1.1). When parents have been in the sessions, their role was that of companion but not of playmate (Cook & Cavalier, 1999). Therefore, the impact of the robot on the mother-child interaction remains unknown. Likewise, studies that have used robots were generally conducted in laboratories or a clinical setting. This was in part because some robots were heavy, complex, non-portable and expensive enough to prohibit leaving one in each child's home. The unique natural environments have been children's schools. Thus, how children with CP interact with a robot in their home is unknown.

Finally, studies suggested that some elements of playfulness were observed in research while children interacted with robots. These behaviors are enjoyment, curiosity and active engagement (Cook et al., 1988; Cook et al., 2000). Thus, these playfulness and play-related behaviors support the idea that a robotic intervention during free play likely will improve child's playfulness.

1.5. Maternal Interactive Behavior in Mothers of Children with CP

Parent-child interaction is a crucial component for children's development where both members of the dyad exchange adaptive responses in an interaction that acts as a transactional system (Ganadaky & Magill-Evans, 2003). Mother-child interaction has been studied more than interactions of the child with other members of the family. This interaction is a fundamental basis for the child's psychological development (Bornstein & Tamis-LeMonda, 1989). The mother-child interaction depends on the child's and mother's behaviors. Behaviors demonstrated by mothers during mother-child interactions are diverse including responsiveness, directiveness (also called over-control), affect and warmth among others.

Martin (1989) defines maternal responsiveness as a domain composed of complex and related constructs such as interpersonal sensitivity, empathic awareness, predictability, nonintrusiveness, emotional availability and contingent reactivity. The latter is related to how the actions of one person depend on the actions of the other person in an interaction.

Responsiveness is the appropriate maternal behavior in response to infants' signals both of non distress (e.g., play) and distress (e.g., when children fuss or cry) (Bornstein & Tamis-LeMonda, 1989). Children's development can be enhanced when parents become more responsive by, for example, following "the child's lead" during play (Kim & Mahoney, 2004, p. 31). Mahoney (2008) includes as elements of maternal responsiveness, sensitivity to child's interests, responsivity to child's behaviors, and reciprocity. Maternal responsiveness is positively correlated with children's cognitive development (Bornstein & Tamis-LeMonda, 1989), children's social development (Landry, Smith, Swank, & Miller-Loncar, 2000), and adolescents' cognitive competence (Cohen, et al., 1996).

Attachment theory states that the parents' formula for a secure attachment with their children consists in allowing the child to explore the environment while being available for protection, comfort, delight and organization of the child's feelings when needed . This is only possible when there are clear cues from each interaction partner and clear understanding of and responsiveness to each other's signals (parent and child) (Marvin, Cooper, Hoffman, & Powell, 2002). A secure attachment has a positive impact on the child's self-confidence, effectance, autonomy, mastery motivation and task persistence (Crockenberg & Leerkes, 2000).

Maternal directiveness (also called over-control, interference, or intrusiveness) has been described as maternal behaviors that interfere in the child's ongoing activities by imposing the mother's will (Beckwith & Cohen, 1989). Maternal directiveness has also been described as any behavior where the mother intends to control the child's behavior and guide the child to follow her lead. It includes verbal and nonverbal commands and physical control over the child's behavior during an interaction (Chiarello & Palisano, 1998; Marfo, 1992). Marfo (1992) states four different classes of maternal directiveness: 1) Turn-taking control by the mother, 2) response control, that is the use of any verbal or nonverbal command to elicit responses or performance from the child, 3) topic control, which means that the topics of the interaction are chosen by the mother, and 4) inhibitive control, where the mother limits, interferes with, or finishes a behavior or activity initiated by the child. Mahoney (2008) included as part of maternal directive behavior the parent's rate (pace) of behavior, where more directive parents are faster than those who are less directive.

Maternal affect is any behavior that expresses acceptance and delight with what the child is doing, as well as the animation, inventiveness and warmth expressed by the mother during the play interactions (Mahoney, 2008). Ferland (2005) stated that the mother-child interaction is a cycle of reciprocity of responsive behavior mediated by the pleasure felt by the two members of the dyad. This interaction is crucial for the child's development since if the mother is responsive the child will develop confidence in his abilities to attain goals independently, autonomy, mastery motivation and task persistence (Crockenberg & Leerkes, 2000).

Regarding children with CP, in the last three decades, studies have focused on describing the patterns of interaction between the child with a disability and his or her mother, father or other relatives (Pennington & McConachie, 1999). However, the literature is not abundant. There is agreement that mothers of children with motor impairment are more directive and less responsive than mothers of children without disabilities (Barrera & Vella, 1987; Blacher, Baker, & Kaladjian, 2013; Hanzlik, 1990; Kim & Mahoney, 2004; Kogan, Tyler, & Turner, 1974; Lieberman, Padan-Belkin, & Harel, 1995). The mother-child play interaction is negatively affected not only by the child's motor impairments, but also by the child's motor speech disorders (Pennington & McConachie, 2001). At the same time, children with CP have been more passive, less responsive and more compliant in play interactions with their mothers than are typically developing children (Barrera & Vella, 1987; Lieberman, et al., 1995).

Regarding the affect expressed by mothers, Kogan et al. (1974) found that mothers of children with CP exhibited a reduction in the amount of positive feelings in their play interactions with their children as they grow. Blacher et al. (2013) found that maternal positive behaviours did not decrease over time during free play for mothers of children with CP or Down syndrome.

Explanations for the behaviors of mothers of children with CP have been given. The child's motor impairment may force mothers to take the lead during interactions (Barrera & Vella, 1987; Kogan et al. 1974). Their directiveness may be attributed to overprotection and maternal frustration with the child's low responsiveness leading the mother to be directive to increase the child's arousal level and increase performance level (Lieberman et al., 1995). On the other hand, low maternal responsiveness is attributed to the effort required to stimulate children with severe disability to play. As children quickly lose their interest in objects and events, mother's motivation to communicate and play with her child is reduced, as a normal human reaction (Brodin, 2005).

Interventions have been developed for decreasing maternal directiveness and increasing maternal responsiveness. These interventions have focused on providing the mother with strategies to allow the child to express himself and respond (Hanzlik, 1989; Mahoney & Powell, 1988). Intervention for training mothers to reinforce motor skills in children increased maternal directiveness (Chiarello & Palisano, 1998). This suggests that mother's directiveness is a strategy that mothers use to increase their children's skills. Chiarello and Palisano (1998) have pointed out the difference between directiveness and other kinds of maternal behaviours such as lack of sensitivity or intrusiveness. Directiveness has been conceived of as a "form of adaptive-strategic parenting behavior" (Marfo, 1992, p. 231) that can occur accompanied by warmth, responsiveness and sensitivity (Chiarello & Palisano, 1998). However, excessive directiveness, overprotection and intrusiveness interfere with the development of children's independence and may inhibit the development of a sense of self-competence, exploratory behavior and activity level (Coplan et al., 2006). If the mother expresses excessive directiveness, dominating and leading the mother-child interactions even in play interactions, the child would have few opportunities to engage in free-play and express playfulness; which in turn may interfere with their development. Directiveness that is provided in combination of warmth, responsiveness, sensitivity and scaffolding can promote children's development. For example, a sensitive mother who knows her child's level of development is able to read her child's needs and desires. She allows the child self-direction but is ready with suggestions for effective implementation of what the child wants to do (Mahoney, 2008). This means that it is necessary to develop strategies to reduce excessive maternal directiveness and to make mothers able to provide scaffolding when needed during mother-child play interactions.

1.5.1. Summary and gaps

Most of the reviewed studies related to mother-child interaction were done with infants and toddlers with CP and motor impairments. The findings about changes in maternal behaviors as children grow are mixed. While Kogan et al (1974) found that the amount of mother's positive affect during therapeutic activities tends to decrease as the child grows, Blacher et al (2013) found that maternal positive behaviours during play stayed about the same as children with CP grown up. Many of the reviewed studies indicate the need to investigate mother-child interaction in children when they become older (Barrera & Vella, 1987; Hanzlik, 1989; Kogan, Tyler, & Turner, 1974).

No study has investigated the effect on maternal directiveness and responsiveness when children with disabilities have assistive technology for manipulation. Hanzlik (1989) included seating equipment, a form of assistive technology, but it was only one element of the intervention in her study; thus, it is not possible to identify how much the assistive technology contributed for decreasing maternal directiveness. It is necessary to investigate how assistive technology itself impacts maternal directiveness and responsiveness. Finally, robots as an augmentative manipulative device have the potential to decrease maternal directiveness and increase maternal responsiveness and may impact maternal affect. The fact that the child is provided with a tool to control some objects in the environment, which enhances the possibility for him to make decisions and actively engage and participate in the interaction with his mother.

1.6. Framework for this project

1.6.1. Bundy's approach to play

Bundy's approach to play is clearly under the *rhetoric of play as self* (Sutton-Smith, 2001). In her approach playfulness is the principal element of play because the presence of playfulness transforms any activity into play (Skard & Bundy, 2008). Bundy (1993) links playfulness with innovative problem solving. Thus, to be playful across the life span is more important than engaging in a sport, hobby or engaging in a specific type of play.

The four elements of Bundy's approach to play (intrinsic motivation, control, freedom to suspend reality and frame) have been operationalized in the Test of Playfulness (ToP) (Skard & Bundy, 2008). The ToP assesses the child's disposition to play through aspects such as the control the child has of the activity, the child's engagement during the activity, the elements of reality that the child suspends, and the enjoyment the child expresses.

1.6.2. The Human Activity Assistive Technology Model (HAAT) Model

The HAAT model constitutes a general framework for this project. This model has four elements, the Human, the Activity, the Assistive Technology and the Context in which the other three elements are immersed (Cook & Polgar, 2008). Regarding the Human Component, in children with CP the motor output of communication, mobility and manipulation is limited, and they need the assistive technology component to enable them to interact with the environment. *Activity* is the fundamental element of the HAAT model because it defines the objective of the assistive technology system. In this case the activity is free play. The objective is that the component *Human* (the child with CP) engages in free play with objects. The element *Assistive Technology* is the robot, which is operated by the child through switches. The robot movements are the output. Thus, in this specific activity, the child operates the robot to play, to interact and to manipulate objects. Regarding *Context*, the child's play is carried out at home and the playmate is his or her mother.

The HAAT model supports the notion that the availability of the robot as an augmentative manipulative device positively affects the child's playfulness. Thus, while using the robot to play, to interact and to manipulate, the child would have an opportunity to experience play. The child would be actively engaged in the activity since she or he has a tool that allows her or him to have an impact on the environment.

1.6.3. Let's Play Model

Let's Play is a model for interventions oriented towards promoting play through AT in children with disabilities (Lane & Mistrett, 2002). The model values play and playfulness as an end in itself; thus, children's play and playfulness are the outcomes of the intervention for children with disabilities and their families. Children with disabilities have the opportunity to enhance their current interest and skills through engaging in free play, rather than focus on skills for the next developmental step. The core characteristics of this model of intervention are: 1) interventions are based on Assistive Technology as a tool to facilitate play and development; 2) the selection and adaptation of assistive technology is family-centered; and, 3) the focus of intervention is play. Additionally, this model states that interventions for children with disabilities should teach the families about the value of play, so they dedicate time exclusively to play at home. These characteristics emphasize the use of assistive technology to support parent-child play interactions in natural environments (Lane & Mistrett, 2002).

1.7. Significance of this study

Providing a robot for assistive play allows children with CP the opportunity to activate the cycle of reinforcement of play and playfulness (see Figure 1.1). The robot as an augmentative manipulation device allows the child to access the object of interest. The object generates the question: *What can I do with the object?* For this kind of interaction, the complete question would be: *What can I do with these objects through the robot?* The child would have a tool to engage in diversive exploration of the environment in a playful way. This interaction using the robot would be more likely to be carried out in a flow state because there was more balance between children's skills and the challenges of the environment. Consequently, the child would actively engage in a totally absorbing activity and experience intrinsic motivation and internal control. As the child gained control of the activity and expressed playfulness, the mother's directiveness would decrease and the mother's responsiveness would increase; thus, the child would have a more supportive playmate to allow engagement in free play. The mother's perception of her child's performance and satisfaction with that performance in play activities would change positively. As the child experiences enjoyment of his or her own skills, self-control, intrinsic motivation and control on some elements of the environment, the child would want to repeat the activity. This is an opportunity to practice skills. Practicing reinforces play skills; thus, the child would be prepared for a new challenge. This cycle would drive the development through free play using the robot as an augmentative manipulative device or as a toy.

1.8. Objectives

The objectives of the pilot study were: 1) to know the stability of data of the main dependent variable (playfulness) in repeated measures which was used to assess the baseline stability; 2) to identify additional factors that could affect the dependent variable at home and that needed to be controlled, and 3) to assess the clarity of the instructions to the participant and her mother.

The objectives of the main study were:

- Investigate the effect of a robot-based intervention for promoting free play on: 1) the child's playfulness; 2) mother's directiveness, responsiveness, and affect/animation, and 3) mother's perceptions of the child's play performance and her satisfaction with the performance.
- Identify the mother's satisfaction with the intervention.

1.9. Questions and Hypothesis

Question 1A: Do the ToP scores (measure of playfulness) of children with CP increase during the intervention when a robot as an augmentative manipulation device is available for free play with their mother in a natural environment compared to the baseline?
Hypothesis 1A: The ToP scores (measure of playfulness) of children with CP will increase during the intervention when a robot as an augmentative manipulation device is available for free play with their mothers in a natural environment compared with the ToP scores in the baseline.

Question 1B: Is there a change in the ToP scores (measure of playfulness) of children with CP following the intervention (availability of a robot as an augmentative manipulation device for free play) in comparison with the baseline?

Question 2A: Does the mothers' directiveness decrease during the intervention while their children with CP are able to use a robot as an augmentative manipulation device during free play in a natural environment compared with the baseline?
Hypothesis 2A: Mothers of children with CP will show significantly less directiveness during the intervention when their children are able to use a robot as an augmentative manipulation device during free play in a natural environment compared with the baseline.

Question 2B: Is there a change in the mothers' directiveness following the intervention (availability of a robot as an augmentative manipulation device during play) compared with the baseline?

Question 3A: Does the mothers' responsiveness increase during the intervention while their children with CP are able to use a robot as an augmentative manipulation device during free play in a natural environment compared with the baseline?
Hypothesis 3A: Mothers of children with CP will be significantly more responsive during the intervention when their children are able to use a robot as an augmentative manipulation device during free play in a natural environment compared with the baseline.

Question 3B: Is there a change in the mothers' responsiveness following intervention (availability of a robot as an augmentative manipulation device during play) compared with the baseline?

Question 4: Is there a change in the mothers' affect/animation either during or after the intervention (availability of a robot as an augmentative manipulation device during play) compared with the baseline?

Question 5: Is there a change in mother's perceptions of their child's occupational performance in play following intervention (availability of a robot as an augmentative manipulation device for free play) compared with the performance before the intervention?

Question 6: Is there a change in the mother's satisfaction with their child's performance in play following intervention (availability of a robot as an augmentative manipulation device for free play) compared with satisfaction before the intervention?

Question 7: How satisfied is the mother with the intervention?

2. METHODOLOGY

This chapter begins with a description about the pilot study that was conducted prior to the main study. The second part of this chapter is a detailed presentation of the methods for the main study.

2.1. Pilot Study

2.1.1. Participant

Ethics approval was obtained from the Ethics Review Board of the University of Alberta. A 4 year 7 month old girl with a diagnosis of cerebral palsy with spastic quadriplegia participated in this study with her mother. They lived in Edmonton, Canada and were English speakers. Her gross motor skills were level IV according to the Gross Motor Function Classification System (GMFCS) (Palisano et al., 2007) and level IV according to the Manual Ability Classification System (MACS) (Eliasson, et al., 2006). She was able to sit on the floor without equipment for positioning, and was also able to creep on her stomach and crawl on her hands and knees very slowly. Her verbal language skills were limited, and her speech was only understood by those who knew her very well. She was able to say yes and no and follow two-step instructions. She could hit the switches controlling the robot with her hands. According the Pictorial Test of Intelligence (PTI-2), her cognitive age was lower than 3 years (French, 2001). She tended to play with the same toys in the same way all the time and had problems focusing and engaging in an activity.

2.1.2. Design and methods

This study was an AB design pilot study for a future multiple baseline design (MBD) across subjects. It was conducted at the participant's home where she played with her mother and her own toys. They chose 16 different toys (e.g., Ernie doll, walker toy, blanket, toy beaded necklace) to play with during the study. The mother-child dyad played on the floor. The toys were 1 meter from the participant. The 15 minute sessions were video recorded and were conducted twice a week for 5 weeks. The child's playfulness was assessed through the Test of Playfulness (ToP) Version 4.2 during the entire study (Bundy, 2010). The study had two phases: a baseline (A) and an intervention (B). During the baseline (two weeks), the girl and her mother played together four times with the set of toys. The stability of the baseline was assessed through visual inspection. Once the level of playfulness showed stability, the baseline phase was ended. The participant was then trained in the robotic skills according to an established protocol (Encarnação, et al., 2013) during 3 sessions over one week. Training sessions were between 20 and 30 minutes long, depending on the participant's tolerance with the activity. After the one-week of training, the intervention started. During the intervention the robot was available during the mother-child free play sessions. During the intervention sessions they played four times over two weeks.

2.1.2.1. Materials

The robot was a Lego MindStorms ® "rovertbot" vehicle with a scoop on the front and was used in previous studies (Cook, et al., 2011; Poletz, et al., 2010). The participant operated the robot using three switches (forward, left turn and right turn) through an adapted infrared remote control (See Figures 2.1 and 2.2). The three switches were located on a board on the floor. The robot was programmed using the Lego Intervention System 2.0 programming language.

2.1.3. Data Analysis

Raw ToP scores were graphically plotted for visual comparison between phases. Statistically significant changes in level of the scores were determined using the 2-standard deviation (2 SD) band method. At least two consecutive data points of the intervention phase must fall outside the two standard deviation band of baseline measures for there to be a significant difference (Portney & Watkins, 2008).

2.2. Main Study

2.2.1. Participants

The sample was non-randomly selected. The sample consisted of 4 children with Cerebral Palsy and their mothers. They lived in Bogotá, Colombia and were Spanish speakers.

Approval from the Health Research Ethics Board at the University of Alberta was obtained for conducting the study in Edmonton (Appendix A). Approval was also obtained for conducting research at the Alberta Health Services and both the Edmonton Catholic and Edmonton Public Schools. The recruitment activities started immediately after the study was approved (Appendices C and D). However, the researcher faced difficulties recruiting participants in Edmonton; thus six months after the study was approved, the Health Research Ethics Board at the University of Alberta approved the addition of Bogota, Colombia as another setting for the study (Appendix A). The Ethics Research Committee of the School of Medicine and Health Sciences at the Universidad del Rosario in Bogota, Colombia approved the study protocol to be conducted in this city (Appendix B). The four participants for the main study were recruited in Bogota, Colombia. Participants were recruited though therapists working in institutions for children with disabilities. If therapists identified a child who met the inclusion criteria, they informed the parents about the study. If the family showed interest in participating in the study, the children's therapists arranged an appointment. In that appointment the researcher met the parents and the child at the rehabilitation institution and explained the study. Participants gave consent to take part in the study (Appendices E, F, and G). Ten families were informed about the study by therapists before the four participants who met the inclusion criteria agreed to participate.

2.2.1.1. Inclusion Criteria

- Children between 4 and 9 years of chronological age. This range of age was selected because previous research has found that 5-year-old typically developing children are able to use the robot for performing the basic robotic skills using three switches.

However, some 4-year-old children understand at least how to make the robot move forward and turn it left or right (Poletz et al, 2010) which is sufficient to use the robot for playing. In addition, some children with cerebral palsy who scored lower than 5 years old according the PTI-2 (see section 2.2.3) still had the cognitive skills for operating the robot in two or three of the basic skills (see section 2.6.2.2 Training Table 2.7) (Encarnação, et al. 2013).

- Consistent with the problem investigated in this study, participants were children with severe motor impairment with a Cerebral Palsy diagnosis within the following levels of gross motor and manual function:
  - Children within the IV and V level of the Gross Motor Function Classification System (Palisano et al., 2007).
  - Children within level IV and V in the Manual Ability Classification System (MACS) (Eliasson, et al., 2006).
- Children who had the ability to express choices and answer yes/no questions.
- Children who were able to follow a two-step instruction. For example, children who follow single instructions such as: "Take this toy and put it inside the box," "pick up a toy and hand it to the mother\therapist."
- Children who were able to make the robot move forward and make the robot turn (left or right) using two switches as assessed by the researcher.

2.2.1.2. Exclusion Criteria

- Cognitive limitations that prevent understanding a two-step verbal instruction. This was needed for the research methodology.
- Vision impairments such that the child is unable to identify toys four feet away even with correction.
- Hearing impairments such that the child is unable to hear conversations with parents.
- Child's mother has cognitive, communication or sensory impairments because these types of limitations likely create confounding effects.

- Families that do not play with their child with cerebral palsy at least two times a week. The frequency in which the mother typically plays with her child was maintained as much as possible throughout the study in order to avoid confounding effects.

2.2.1.3. Participants' descriptions

Table 2.1 shows the description of each of the participants (child and mother) in the study; information about the children's play and mother's contextual factors is provided below. A coding system using number and letters was used for each participant in order to correlate the results of each mother-child dyad, i.e. MP01 is P01's mother, MP02 is P02's mother, MP03 is P03's mother, and MP04 is P04's mother. Descriptive information of the participants came from the following measures:

The Pictorial Test of Intelligence – PTI-2: the child's cognitive level was assessed through the PTI -2 (French, 2001). Cognitive level is related to children's playfulness (Chang, et al., 2014) and to the robotic skills achieved by children with CP (Encarnaçao, et al., 2013). The PTI-2 is a test of general intelligence that does not require manipulation or verbal communicative skills for answering the questions. The test is normed for use with children who have motor impairment. The PTI-2 has content validity, criterion-prediction validity, and construct-identification validity (French, 2001). An examiner who has formal training in assessment (French, 2001) can administer the test. A psychologist at the Glenrose Rehabilitation Hospital who had experience in administering and interpreting the test trained the researcher.

The PTI-2 has three subtests: verbal abstractions, form discrimination and quantitative concepts. Subtest scores provide age equivalence for the child for each subscale. Combined scores provide a Composite Quotient that is a global index of performance in seven categories from very poor to very superior. The PTI-2 has been used to assess the cognitive level of children with motor impairment in previous robotic research (Encarnação, et al., 2011; Encarnação, et al., 2013). Since the PTI-2 was developed in English, sentences for each question were translated to Spanish by bilingual researchers using the Direct Translation Technique

(Høegh & Høegh, 2009) in a previous study (Cook, et al., 2012). This measure was completed before the study sessions started.

The Initial Interview with Parent on the Ludic Behaviour of the Child (IIP): the purpose of the IIP is to gather information about the child's play behavior at home (Ferland, 2005). The IIP has eight sections that provided information about the child's play material, toy preferences, play interests, stimuli interests, favorite playmates, most functional position to play and frequency of play with different members of the family. The IIP (Ferland, 2005) was used to identify the patterns of the child's play in the family environment. Since this IIP is in English, the English version was translated to Spanish and the translation was validated using a back translation technique (Cha, Kim, & Erlen, 2007). This measure was completed before the study sessions started.

Social Support Questionnaire - Short Form (SSQ-6), Version in Spanish: maternal behavior is influenced by different factors. Belsky's model of determinants of parenting points out that maternal behavior is directly influenced by three forces or factors, individual characteristics of the mother (personality and developmental history), characteristics of the child (child's behavioral styles that make parenting less or more difficult; e.g. child's temperament); and from an ecological perspective, contextual forces (the overall contextual support in terms of marital quality, emotional support, assistance with parenting related tasks and social information about the parental appropriate behavior, and also contextual sources of stress (Belsky & Jaffee, 2006). In the current study, contextual forces that could affect the maternal behaviour toward the child were assessed though the Social Support Questionnaire - Short Form (SSQ-6) (Sarason, et al., 1987). The SSQ-6 assesses perceptions of the number of people providing support and the respondent's satisfaction with such support. There are six questions; each question requires a two-part answer. The first part asks the number of perceived social support sources (SSQ-N) – from none to nine possibilities – and the respondent indicates the type of relationship with the person listed (e.g., husband, sibling, friend). In the second part, the respondents report how satisfied they are with the social support received (SSQ-S), on a six-point Likert scale that ranges from 'very dissatisfied' (score of 1) to 'very satisfied' (score of 6). The internal reliability of the SSQ-6 ranged between 0.90 to 0.93 for both number and satisfaction. The SSQ-6 has a satisfactory test-retest reliability (Sarason, et al., 1987). The Spanish version of this scale was used (Marrero Quevedo & Carballeira Abella, 2010). This measure was completed before the study sessions started. In addition to this questionnaire, mothers reported who help them with parenting. They also reported any situation that was generating stress in their lives during the study. Social-economic strata (SES) and hours outside home are associated with maternal responsiveness (Blacher et al., 2013; Smith, 2010), thus this information was also collected.

Table 2.1 Participants' Description

Child							Mother			
Code	Chron. age	Cognitive age according to PTI-2	Gender	GMFCS Level	MACS Level	Language	Code	Age	Occupation	Highest educational level
P01	5 y/ 5 m	VA: 7-0 FD: <3-0 QC: <3-0 PIQ: 89 (80-89= below average)	Male	V	IV	Good level of spoken language.	MP01	34	Housekeeping	Grade 10 in High school was not completed
P02	9 y/ 4 m	VA: 3-3 FD: 3-3 QC: 3-3 PIQ: 42 (35-69= very poor)	Female	V	V	Very limited spoken language. She does not initiate a conversation but responds to questions using few words (e.g. yes, no, OK, good)	MP02	33	Housekeeping	Technical college.
P03	6 y/ 4 m	VA: 4-6 FD: 3-6 QC: 4-6 PIQ: 74 (70-79= poor)	Male	V	V	Limited spoken language, tries to communicate other ways.	MP03	33	Housekeeping	High school completed
P04	8 y/ 11 m	VA: 6-9 FD: 6-9 QC: 6-9 PIQ: 83 (80-89= below average)	Male	IV	III-IV	Very limited spoken language, tries to communicate other ways.	MP04	38	Nurse	Technical college.

Notes:
VA: Verbal Abstractions; FD: Form discrimination; QC: Quantitative Concepts; PIQ: Composite Quotient

P01 and MP01: MP01 was interviewed using the IIP (Ferland, 2005) and reported that her 5-year-old son lives with two siblings. He always plays with the same objects (toy cars, toy piano), and usually rejects new play materials when they are offered by his mother. He mostly plays indoors at home. He does not like to be in new places. His favorite activities are to color a paper with the assistance of his mother and pretend to use a computer. His least favorite activity is to watch television. His favorite position for playing is sitting in a baby walker. P01's favorite and most common playmates are his 8-year old brother and 16-year old sister. His mother describes him as a child who is curious, takes initiative, has a sense of humor, and is spontaneous. His mother uses verbal explanations, demonstrations, and gestures to make herself understood by him and he uses mainly words and phrases to express himself. He attends kindergarten every weekday, except Thursdays. On Thursday mornings he goes to a rehabilitation centre. He plays every day after school with his siblings and his mother joins these play activities as she is able. The family spends most of the weekends at home because going into the community is expensive for the family because of the cost of public transportation.

The Social Support Questionnaire - Short Form (SSQ-6) revealed that three people provide social support to the mother: her father, sister, and a friend (average score was 1.17. Nobody helps her to feel more relaxed when she is under pressure or tense. Her average satisfaction with the social support was 5.17. MP01 reported that a complicated relationship with her teenage daughter was generating stress in her life. She also expressed that, despite living with her husband, no one helps her with parenting challenges or child-care tasks. Her daughter used to help her, but at the time of the assessment, it was very infrequent. She obtains support and information about parenting challenges and strategies from the staff at the rehabilitation centre. MP01 also reported obtaining access for P01 to rehabilitation services was a source of stress. MP01 and P02 belonged to a very-low Social-economic stratum[1] (SES).

P02 and MP02: MP02 reported during the IIP that her 9-year-old daughter is the only child. P02 likes to be engaged in activities that involve water or grass and loves noisy environments (e.g., where many people are talking around her). P02 always needs help to play. Her favorite play activity is to color on a paper with assistance and her least favorite activities

[1] Socio-economic status (SES) was based on the classification established by the government of the city according to its geographical characteristics (locality, zonal planning unit, and neighborhoods) because the SES index as traditionally calculated is not available in Colombia.

are fine motor activities, especially when she is asked to use her left hand. Her favorite position for play is sitting on the floor with support. MP02 describes P02 as a child who likes to have fun, is curious, does not like challenges, and never takes initiative. P02 uses mainly vocalizations and gestures to express herself. MP02 uses words and verbal explanations to make herself understood by P02. P02 is not attending school.

The Social Support Questionnaire - Short Form (SSQ-6) revealed that three people provide social support to MP02: a friend, her husband and her mother (average per question 1.67). MP02's average of satisfaction with the social support was 4.83. MP02 reported that her husband and her mother help her with parenting challenges and children care tasks. She obtains support and information about parenting challenges and strategies from the staff at the rehabilitation centre. MP02 also reported that making decisions about medical treatments (e.g., rhizotomy) for P02 is generating stress in her life. MP02 and P02 belonged to a medium SES.

P03 and MP03: MP03 reported during the IIP that her 6-year-old son is an only child, but he lives with three cousins: an 11-year old boy, a 9-year old girl, and an 11 month boy. P03's favorite and most usual playmate is his girl cousin. P03's favorite activity is to watch movies and listen to music; his favorite position for playing is sitting in his wheelchair. His least favorite activity is to grasp toys. MP03 describes P03 as a child who is curious, takes initiative, has a sense of humor, has fun, enjoys challenge and is spontaneous. For communication, P03 uses words and phrases to express himself; however, some times MP03 finds it difficult to understand what he is saying. MP03 uses words and verbal explanations to make herself understood by P03. P03 is not attending school; his mother is looking for a school. P03 is not attending the rehabilitation center due to recent hip surgery for dysplasia. P03 spends all day at home, watching movies and sometimes he goes outdoors with his mother.

The Social Support Questionnaire - Short Form (SSQ-6) revealed that two people provide social support to MP03: her father and mother (average per question 0.83). Nobody helps her to feel more relaxed when she is under pressure or tense, or helps her to feel better when she is feeling generally down-in-the-dumps, or consoles her when she is very upset. MP01's average of satisfaction with the support was 4. She reported that her father and mother help her with parenting challenges or children care tasks. She obtains support and information about parenting challenges and strategies from the staff at the rehabilitation centre that P03 attends. MP03 also reported that a complicated economic situation and finding school for P03 is generating stress in her life. MP03 and P03 belonged to a low SES.

P04 and MP04: MP04 reported during the IIP that her 8-year-old son has a 6-year old sister. P04's favorite play activities are playing computer games (which he is able to do) and watching movies. His favorite position for playing is sitting in a chair. P04's favorite and most usual playmates are his sister and his father. His least favorite activity is to do homework after school. MP04 describes P04 as a child who is curious, takes initiative, has a sense of humor, has fun, enjoys challenge and is spontaneous. For communication, P04 uses particular facial expressions and gestures to express himself. MP04 uses words and verbal explanations to make herself understood by P04. P04 is attending school (second grade basic school). P03 attends the rehabilitation center every afternoon.

The Social Support Questionnaire - Short Form (SSQSR-6) revealed that seven people provide social support to MP03: mainly her husband and mother; she also can count on her three siblings, a friend and her mother in law (average per question 3.17). MP04's average of satisfaction with the support was 5.67. MP04 reported that her husband, her mother, her siblings and mother in law help her with parenting challenges or parenting children care tasks. She also expressed that she obtains support and information about parenting challenges and strategies from the staff at the rehabilitation centre that P04 attends and from the hospital where she works. MP04 also reported as a source of stress the educative services that P04 was receiving at school. In spite of her job as a nurse, MP04 was at home when P04 returned from school every day. MP04 and P04 belonged to a medium SES.

2.2.1.4. Sample Size

This study meets the general rules of single case research regarding the number of participants (minimum three) (Kazdin, 2011). This study also meets the guidelines proposed by the American Academy for Cerebral Palsy and Developmental Medicine in regard to the design of single case research which requires at least three baselines (participants in this case) (Logan, Hickman, Harris, & Heriza, 2008). Regarding the number of data points, the baseline and the intervention phases had at least five data points, which is critical for performing statistical analysis of the baseline stability and the effect of the intervention. The Follow-Up phase had three data points which is sufficient for assessing carry over effects in previous single case designs (Fox & Boliek, 2012) .

2.3. Setting and Materials

2.3.1. Setting

As a familiar environment is essential for assessing free play (Skard & Bundy, 2008) the children's natural environments (home and rehabilitation center) were the setting for the study. The pilot study was conducted at the child's home. For the main study, P02, P03 and P04's setting was home. P01's setting was the rehabilitation center he attends as he lived in an unsafe neighborhood that posed a potential threat for the researcher and the robot. The sessions were carried out as convenient for the families, during the time the mother usually used for doing activities such as playing with the children, reinforcing skills, doing homework or resting after school.

2.3.2. Materials

Robot: The Lego Invention "roverbot" vehicle[2] vehicle with a scoop was used (See Figure 2.1 and 2.2). These robots have been used in previous studies (Cook et al., 2011; Corrigan et al, 2007; Poletz et al., 2010). Children operated the robot using switches through an adapted infrared remote control (see Figure 2.3). The robot was programmed using the Lego Intervention System 2.0 programming language as done in the studies mentioned above. The switches were placed according to each child's motor skills considering child's position, movement patterns (voluntary and consistent), and control site. The types of switches were selected so that the movement was performed with minimal fatigue (Tash Inc., 1996). Table 2.2 shows a description of the switches location of the switches and robot programs used for each child.

[2]http://www.lego.com/en-us/Default.aspx

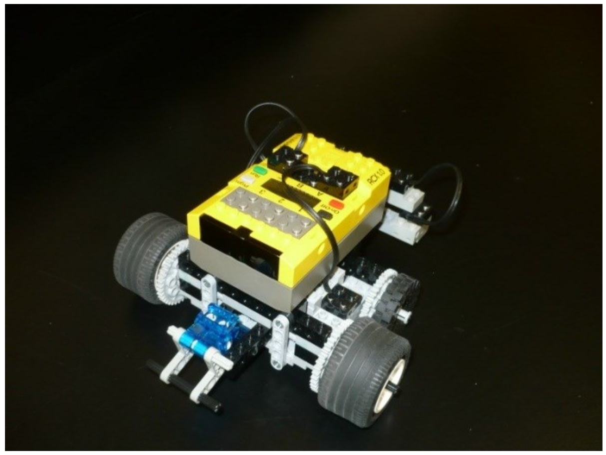


Figure 2.1 Lego Invention “roverbot” vehicle.

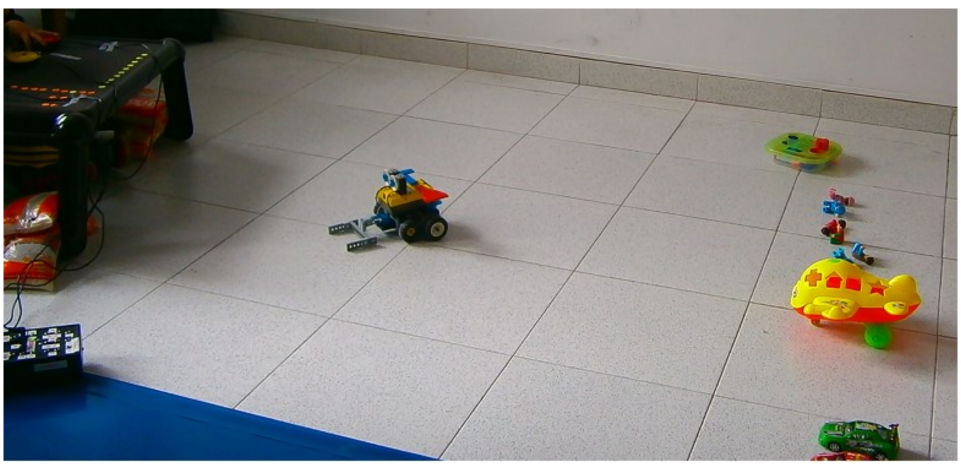


Figure 2.2 The roverbot used by P01 during one of the play sessions.

Table 2.2 Children's research conditions

Particip.	Child's position	Child's motor patterns	Robot programs	Switch location	Robot design for easy use of the switches	Type of switches
P01	Sitting on the floor in a sitter chair	Right hand	Forward: while hitting the switch	Yellow switch (with eyes drawn on it) located on a tray	Eyes on the front of the robot	Jelly bean
		Right hand	Turn right: 45 degrees	Blue switch located on the right side of a tray	Blue arm on the robot's right side	Jelly bean
		Left hand	Turn left: 45 degrees	Red switch located on the left side of a tray	Red arm on the robot's right side	Jelly bean
		Head	Backward: While hitting the switch	Blue switch located behind to the right side of the child's head. This switch was attached to the sitter chair using a mounted arm.	Nothing	Jelly bean
P02	Sitting on the floor in a sitter chair	Right hand	Forward: While hitting the switch	Yellow switch located on a tray	Eyes on the front of the robot	Jelly bean
		Right hand	Turn right: 45 degrees	Purple switch located on the right side of a tray	Purple eyebrow on the robot's right eye	Jelly bean
		Right or left hand	Turn left: 45 degrees	Blue switch located on the left side of a tray	Blue eyebrow on the robot's left eye	Jelly bean

Particip.	Child's position	Child's motor patterns	Robot programs	Switch location	Robot design for easy the switch use	Type of switches
P03	Sitting in his wheelchair (because of a recently performed hips dysplasia surgery)	Left forearm	Forward: while hitting the switch	Blue switch (with eyes drawn on it) attached to the wheelchair using a mounted arm.	Eyes on the front of the robot	Jelly bean
		Head	Turn right: 45 degrees	Green switch attached to the wheelchair's right side using a mounted arm.	Green arm on the robot's right side	Jelly bean
		Head	Turn left: 45 degrees	Blue switch attached to the wheelchair's left side using a mounted arm.	Blue arm on the robot's right side	Jelly bean
		Left feet	Backward: While hitting the switch	Blue switch located on an adapted foot-rest attached to the wheelchair.	Nothing	Jelly bean
P04	Sitting on his a chair using hips strap . In spite of the fact the child was able to sit on the floor without supporting system, he felt unsafe in this position.	Right hand	Forward: while hitting the switch	Blue switch on a tray.	Eyes on the front of the robot	Jelly bean
		Right hand	Turn right: 45 degrees	Blue switch located on the right side of a tray	Nothing	Jelly bean
		Right hand	Turn left: 45 degrees	Blue switch located on the left side of a tray	Nothing	Jelly bean
		Head	Backward: While hitting the switch	Blue switch located on the left side of a tray	Nothing	Jelly bean

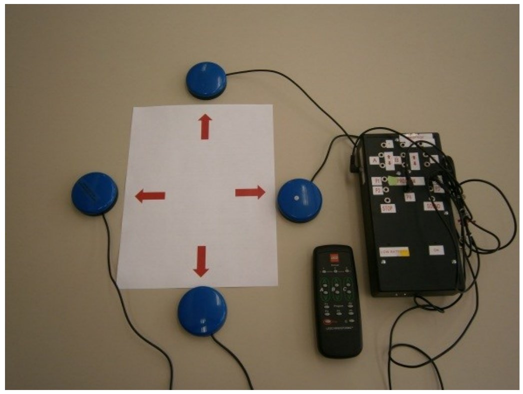


Figure 2.3 Adapted infrared remote control

The adapted remote control has the same functionality (on the right of the picture) as the original remote control, but allows switches to be plugged in to it. The blue push button switches (on the left of the picture) are shown with a diagram illustrating the functionality of each switch relative to robot movements.

Equipment for positioning participants: Participants used equipment for positioning according to their sitting posture (See Table 2.2). P01 and P02 were provided with a sitter chair and a tray that was located on the floor. P03 and P04 used their own chairs and trays.

2.4. Study Design and Protocol

The design used in this study was a partially nonconcurrent multiple baseline design across subjects (Lumpkin, et al., 2002).This is a variation of the traditional multiple baseline design that has been called a nonconcurrent multiple baseline design (Barlow, Nock, & Hersen, 2009; Watson & Workman, 1981) or a multiple baseline design where the assessment begins at different points (Kazdin, 2011). The nonconcurrent variation is useful when participants are not available at the same point of time for practical reasons (Watson & Workman, 1981). In the nonconcurrent multiple-baseline design proposed by Watson and Workman (1981), the researcher initially determines the length of each baseline; then, participants are randomly assigned to predetermined baseline lengths as each participant becomes available. The partially nonconcurrent multiple baseline design has advantages over the usual nonconcurrent multiple baseline design because some participants provide a partial control for the effects of history (as their baselines overlap in time) while some participants provide replication (Lumpkin, et al., 2002). In the present study, the prearranged number of baseline sessions for each participant was five, six, seven and eight. Because there was a training period between the baseline and the intervention, these short duration baseline phases were chosen so that the participants would not have to wait for long periods before receiving the intervention. A short baseline period also diminished the possibility that maturation was operating as a confounding variable. Participant assignment to the actual number of sessions was made once the stability in the baseline scores was assessed rather than before the baseline as suggested by Watson and Workman (1981) who suggest assuming stable baselines a priori to the data collection. This modification to the traditional nonconcurrent design was done in order to ensure one of the main requirements of the single-case design: stability in the baseline. Thereby, for this study, if the baseline was stable at the fifth session; then, the number of baseline sessions was randomly assigned between five, six, seven or eight. If at session five the baseline was not stable, the participant was assigned to have eight baseline sessions. Eight sessions were selected because this number of baseline data points allows statistical comparison between phases without-stable baselines (Tryon, 1982). Thus, in this study, there were 3 randomly assigned baseline lengths and one non-randomly assigned baseline length. In addition, the baselines of P01, P02 and P03 overlapped in time providing a source of control for the effects of history, while P04 provided replication.

In order to answer the research questions this study had three phases: A baseline, an intervention and a follow-up. During the entire study each child-mother dyad played together with the child's own toys. This study assessed the effects of a robotic intervention on different aspects of the child's play experience (see dependent variables). Therefore, during the baseline and the follow-up phases the children and their mothers played without the robot. The average total length of the study was 16 weeks (from 14 to 18 depending on the participant). The length of the baseline, and the training sessions were different for each participant, while the intervention and the follow-up phases were planned to be the same length for each participant. This was 10 sessions during 5 weeks for the intervention and 3 sessions during the follow-up (the first one right after the intervention ended; the second, about two weeks after the intervention ended; and the third, about one month after the intervention ended). However, due to some circumstances out of the researcher's control[3], the length of the intervention was a little different for participants P01 and P03. P01 missed two sessions in the same week. These sessions were replaced in an extra week. P03 missed one session which was replaced with an extra session. Table 2.3 shows the length of each study phase for each participant.

Table 2.3. Study length for each participant

Time	Month	July					August				September				October					Nov
	Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	Dates	1-6	7-13	14-20	21-27	28-3	4-10	11-17	18-24	25-31	1-7	8-14	15-21	22-28	29-5	6-12	13-19	20-26	27-2	3-9
Participant	P01	B1	B2 B3	B4 B5	B6 B7	B8 T1	T2 T3	T4	I1 I2		I3 I4	I5 I6	I7 I8	I9 10	F1	F2			F3	
	P02				B1	B2 B3	B4 B5 T1	T2 T3 T4 T5	T6 T7	T8 I1	I2 I3	I4 I5	I6 I7	I8 I9	I10 F1		F2		F3	
	P03			B1	B2 B3	B4 B5	B6 T1	T2 T3	T4 I1	I2	I3 I4	I5 I6	I7 I8	I9 10	F1		F2		F3	
	P04						B1	B2 B3	B4	B5 B6	T1 I1	I2 I3	I4 I5	I6 I7	I8 I9	I10 F1		F2		F3

Notes:
B=Baseline sessions; T=Training sessions; I=Intervention sessions; F=Follow-Up sessions

The sessions were conducted twice per week. Each session was 15 minutes long. The sessions were planned to be carried out according to the schedule agreed with the families as presented in Table 2.4.

Table 2.4 Participant's schedule and locations

Participants	Days	Time	Location
P01 and MP01	Tuesday and Thursday	9:00 am	Rehabilitation Centre: Occupational Therapy room
P02 and MP02	Monday and Thursday	2:00 p.m.	Home: Living room
P03and MP03	Monday and Friday[4]	12:00 p.m.	Home: Grandmother's bedroom
P04 and MP04	Monday and Wednesday	4:00 p.m.	Home: Dining room

[3] There was a strike in the city which resulted in the road for accessing the children's neighborhood and rehabilitation institution being blocked.

[4] During the baseline the sessions were conducted Monday and Wednesday. Then, the mother asked to change the sessions to Friday instead of Wednesday. This was because P03's special educator changed her schedule, so P03's special education appointments were scheduled every Wednesday.

2.5. Variables and Measures

2.5.1. Independent Variable

The independent variable was the robotic intervention. The researcher brought the robot to each child's research setting (home or rehabilitation institution). Thus, the robot was available to the mother-child interaction only during the free play sessions of the intervention phase. The robot plus the switches and the mounted equipment as an augmentative manipulation device was the assistive technology for performing the activity of play.

2.5.2. Dependent Variables

The dependent variables were: 1) the child's playfulness, 2) maternal directiveness, 3) maternal responsiveness, 4) maternal affect/animation, and 5) mothers' perceptions of the child's play performance and satisfaction with the child's play. A description of the variables is presented followed by the way they were measured. These variables are presented together in Table 2.6.

2.5.2.1.Children's Playfulness

Playfulness was measured using the Test of Playfulness (ToP) version 4 (Skard & Bundy, 2008). The ToP is a standardized test that assesses playfulness in children between 6 months and 18 years of age. The ToP has 29 items that can be scored directly or by viewing a video record. These 29 items reflect four elements of playfulness: Intrinsic motivation, Control (internal and share), Freedom to suspend reality and the Frame (Skard & Bundy, 2008). Each one of the 29 ToP items is related to one of the elements of playfulness as shown in Table 2.5. Each item is rated on a four-point scale, from 0 to 3. This scale reflects extent, intensity and/or skillfulness on the items (Bundy, Nelson, Metzger, & Bingaman, 2001). Although the ToP was designed to be administered indoors and outdoors, for the purposes of this study it was only administered indoors.

Table 2.5. Elements of playfulness in the ToP

Intrinsic Motivation	Internal Self Control	Shared Self Control	Freedom from unnecessary constrains of reality	Framing
• Engaged o Extent o Intensity • Process o Extent • Persist o Intensity • Affect o Intensity	• Decides o Extent • Safe o Extent • Modifies o Skill • Interacts with objects o Intensity o Skill • Transitions o Skill	• Negotiates to get needs met o Skill • Engages in social play o Extent o Intensity • Supports play of others o Skill • Enters a group already engages in an activity o Skill • Shares o Skill	• Mischief / Teasing o Extent o Skill • Pretends o Extent o Skill • Clowning / Joking o Extent o Skill • Unconventional / creative use of objects o Extent o Skill	• Gives cues o Extent o Skill • Reads cues o Extent • Engaged o Skill

Adapted from: Rigby P. Test of Playfulness Training session. January 25, 2012

The construct and concurrent validity and inter-rater reliability of the ToP (Bundy et al., 2001) were assessed through how well the scores of each item fit the Rasch model. The Rasch model has three assumptions: "1) Easy items are easy for all people; 2) more playful people are more likely to get higher scores on hard items; and 3) lenient raters are more apt to award high scores on all items than are severe raters" (Harkness & Bundy, 2001, p. 75).The ToP reflects an unidimensional construct of playfulness and 96% of the raters' scores fit the Rasch Model. The ToP scores were moderately correlated to another scale that also assesses playfulness, the Children Playfulness Scale (Barnett, 1991) indicating criterion validity (r=.46) (Bundy, et al., 2001). Harkness and Bundy (2001) found the ToP to be a reliable assessment for children with physical impairments and unknown cognitive limitations.

The test-retest reliability of the ToP has been evaluated in three studies: O'Brien and Shirley (2001); Brentnall, Bundy and Scott (2008); and in an unpublished master's thesis in 2003 (Skard & Bundy, 2008, p. 79). O'Brien and Shirley (2001) assessed the playfulness of five children who were reassessed four years later. They found that although the scores changed in the two evaluations, the scores were consistent with the entire test according to the expectations of the Rasch model; that is, easy items remained easy in the second assessment and hard items were also hard in the second assessment. Brentnall, Bundy, and Scott (2008) applied the ToP to 20 typically developing children in two sessions that were separated by 2-3 weeks. Regarding test-retest reliability they reported an intraclass correlation of 0.67 ($p<0.01$) for the fifteen-minute observations. The ToP is sensitive to changes in playfulness after intervention in typically developing children (Bundy, et al., 2008) and in children with cerebral palsy (Okimoto et al., 1999). These studies have proven that when the ToP is scored by a trained rater, the scores are reliable. Studies also identified factors that may affect ToP scores such as the setting where the child plays, the playmates involved, or if the child plays alone. Prior studies using the ToP provide direction for further studies. The length of the observation should be about 15 minutes, because longer observations affect the reliability and do not provide any additional important information (Brentnall et al., 2008). The environment should be the same for the pretest and posttest measures because playfulness of children with cerebral palsy was not stable across different environmental settings (Rigby & Gaik, 2007). The playmate may affect the ToP scores, in spite of the fact that children with CP have not shown significant differences in ToP scores when playing with their mother versus their father (Chiarello, Huntington, & Bundy, 2006).

The researcher was trained in the ToP application and scoring by Dr. Patty Rigby at the University of Toronto. She was calibrated in scoring the ToP by Dr. Anita Bundy. She followed the standard calibration process which included: 1) scoring videotapes that had been scored by other trained raters, 2) introducing the data into the normative data set, and 3) contrasting her data with the large data base in order to analyze whether the data fit with the Rasch model expectations. This training process has been described in other studies (Bundy, et al., 2001; Chiarello, et al., 2006; Rigby & Gaik, 2007).

In this study the ToP was scored for every session during all phases. The 15 minute sessions was videotaped in order to score the ToP after sessions. When sessions were a bit longer than 15 minutes, only the initial 15 minutes were scored. The researcher did not interact with the child during the play session according to Skard and Bundy's direction (2008). More specifically, the researcher remained in a different room of the home during the play sessions. The ToP was scored during the baseline as the data was collected because the ToP raw scores were used for evaluating the stability of the baseline. The intervention and follow-up sessions were scored after all of the sessions were done. The order of the sessions for scoring was randomly selected; thus, the sessions were not scored in the same order as the data were collected. This helped to avoid bias due to the rater recalling scores from immediately prior sessions and biasing the data.

The raw scores were sent to Bundy in order to get the overall Rasched playfulness score for each session. The ToP scores of each of the 29 items for each session were analyzed using the Rasch analysis computer program Facets 3.71.3 after the data collection. The Rasch analysis converted the score of each of the items into a single ToP measure of playfulness, which ranges from +3 to - 3 (Bundy et al., 2001). Scores with a negative sign indicated that the child was not playful, and scores in the positive direction above zero indicated that the child expressed playfulness during the session (Bundy, et al., 2001; Rigby & Gaik, 2007). The Rasch ToP scores were used to create the plots (see results).

2.5.2.1.1. Inter-rater reliability

A second rater was trained by the researcher and followed the same process described above for her calibration in scoring the ToP. This second rater was an occupational therapist with more than 20 years of clinical and academic experience and was proficient in both Spanish and English. After the two raters were calibrated and prior to scoring the videos, together they scored five videos for additional reliability purposes. These videos were not part of this study. In these videos, three children with disabilities (two with cerebral palsy and one with a developmental delay) and two typically developing children played with their mothers. During this process raters identified that it was difficult to achieve agreement for the items *Engaged-Intensity, Social Play-Intensity* and *Shares-Skill*. In the case of the items *Engaged-Intensity* and *Social Play-Intensity*, the ToP manual presents a description for scores corresponding to the minimal (0) and the maximum (3) values. However, there is no description for the middle values (1 and 2). As a result, although the raters had the same perception about children's behaviour during play, there was disagreement when the score was not the minimum or maximum values. In response to this situation, some examples were added to the description in order to discriminate the scores 1 and 2 in the mentioned items. Regarding the item *Shares-Skill*, it was difficult to identify if a child with severe motor and communication limitations was sharing objects, equipment or ideas with the mother as playmate because it was the mother who manipulated all of the toys. Thus, it was agreed that if the child behaviour did not fit any of the item descriptions, the item would be scored as not applicable (N/A).

During the study, the researcher scored 100% of the sessions and the second rater scored 19 randomly selected sessions. This represented 27.9% of the baseline sessions, 20% of the intervention sessions, and 33.3% of the follow-up sessions. According to personal correspondence with the ToP developer (A. Bundy, personal communication, December, 5, 2013), the inter-rater reliability value was obtained by calculating the confidence interval for each rater. An overlap in the confidence interval indicates that the ToP measures for each rater are not different from each other. The inter-rater reliability was calculated as the percentage of sessions in which the ToP measure of each rater overlapped. The inter-rater reliability of the ToP scores for all participants across baseline, intervention and follow-up sessions was 95%. This means that the confidence intervals of the ToP overall score of the two raters overlapped in 18 out of 19 sessions. They were different in 5% of the sessions (one session baseline, for P03).

Additionally, in order to know if the ToP scores fit the expectations of the Rasch model, the percentage of the total number of scores that failed to fit the model were computed as it has been done in previous studies (Bundy, et al., 2001).

2.5.2.2. Maternal Directiveness and Maternal Responsiveness

Maternal directiveness, responsiveness and affect/animation were measured through the Maternal Behavior Rating Scale revised –MBRS (Mahoney, 2008). This scale has 12 items that are organized in four subscales: Responsive/child oriented (responsivity, sensitivity, effectiveness); affect/animation (acceptance, enjoyment, expressiveness, inventiveness, warmth); achievement orientation (achievement, praise); and directive (directiveness, pace). The items are rated on a 5-point Likert scale with 1 being a low incidence of the particular factor, and 5, a high incidence. For this study all the five subscales were scored. However, only two subscales were used to test the study's hypotheses: Responsive/child oriented and directive. This was due to the evidence that mothers of children with motor and communicative impairment are less responsive and more directive than mothers of typically developing children (Barrera & Vella, 1987;

Hanzlik, 1989; Marfo, 1992; Pennington & McConachie, 2001). However, there is limited evidence that having a child with motor impairment influences either the maternal affect or achievement orientation during play activities. In addition, the literature suggests that a high responsive and low directive style of parenting is an approach that promotes child's development (Kim & Mahoney, 2004; Mahoney & Powell, 1988).

Inter-rater agreement for MBRS scores within one scale point ranged between 93% and 100% (Mahoney & Powell, 1986). In a study of children with motor delays including cerebral palsy, the intra-rater reliability was 0.89 for affect/animation, 0.95 for achievement orientation, 0.97 for responsiveness, and 0.97 for directiveness (Chiarello et al., 2006). This scale is responsive to change in children with disabilities including children with cerebral palsy (Mahoney & Powell, 1988) and has been used in research with mothers and fathers of children with cerebral palsy (Chiarello et al., 2006).

In this study the MBRS was scored in every session during all phases. The MBRS' author for achieving a higher inter-rater reliability (Mahoney, 2008) suggests a time interval between three and seven minutes. Although the videos were fifteen minutes long, only the first seven minutes were analyzed. This decision could impact the validity as eight minutes of the mothr-child interaction were not scored. However the MBRS's developer stated that seven minutes provide enough information about the mother-child interactoion (Mahoney, 2008). The first seven minutes were selected because this interval includes the way in which the mother initiated the play session. The beginning of the session provided important information about the two main mother's variables, responsiveness and directiveness.

2.5.2.2.1. Inter-rater reliability for the MBRS

Scoring of the MBRS started after the ToP was scored for all the sessions. The first step in this process was training in the MBRS. The researcher and the same occupational therapist who served as the second rater for the ToP trained for scoring the MBRS following the "Procedures for Establishing Inter-rater Reliability on the MBRS" provided by Mahoney (2008). Together, the researcher and the second rater scored five 7-minute long videos where two children with a disability (one with cerebral palsy and one with a developmental delay) and three typically developing children were playing with their mothers or fathers. Then, the two raters independently scored five additional 7-minute long videos of two children with cerebral palsy and three typically developing children playing with their mothers or fathers. The inter-rater reliability was compared through the Pearson's r using the IBM SPSS software as recommended by the MBRS's developer (Mahoney, 2008). The Pearson *r* was 0.76 which was higher than the minimum (0.75) required for advancing to the next training step. Then, the raters independently scored ten 7-minutes long videos where three children with a disability (two children with cerebral palsy and one child with developmental delay) and seven typically developing children were playing with their mothers. None of these videos were part of this study.

For the study sessions, the researcher scored 100% of the sessions and the second rater scored 19 randomly selected sessions. This represented 27.9% of the baseline sessions, 20% of the intervention and 33.3% of the follow-up sessions. The order of the sessions for scoring was randomly selected; thus, the sessions were not scored in the same order as the data was collected. This helped to avoid bias due to the rater recalling scores from immediately prior sessions and biasing the data. The inter-rater reliability for the MBRS during the training was Pearson r = 0.947. The inter-rater reliability for the complete study for all participants across baseline, intervention and follow-up sessions was Pearson r = 0.975. The exact agreement for sub-scale items was Responsiveness=95%; Directiveness = 86% and Affect/Animation=95%.

2.5.2.3. Play Performance and satisfaction

The Canadian Model of Occupational Performance (CMOP) states that the occupational performance is the result of interactions between the person (physical, affective and cognitive components), the environment (physical, social, cultural and institutional elements) and the occupation (self-care, productivity and leisure) (Law, et al., 1998). In the CMOP, play is part of the productivity category. The Canadian Occupational Performance Measure (COPM) is based on this model. COPM assesses performance and satisfaction with the performance as perceived by the participant- or the participant's caregiver when the client is not able to report it. In this study the mothers reported the COPM scores. The variables performance and satisfaction with performance were measured four times; at enrollment, at the end of the baseline phase, at the end of the intervention phase, and at the end of the follow-up phase.

Occupational performance and satisfaction was measured using the Canadian Occupational Performance Measure (COPM) (Law, et al., 1998). The COPM measures two aspects: 1) Occupational performance or level of functioning and 2) satisfaction with performance. The COPM has good reliability (Law et al., 1998). Test-retest reliability is acceptable for performance with an intra-class correlation (ICC) of 0.63 and good for satisfaction (ICC = 0.84). For children with disabilities whose parents completed the measure, the reliability was 0.79 for performance, and 0.75 for satisfaction. The COPM has shown content, criterion and construct validity in at least twelve studies and responsiveness in five studies (Law et al., 1998). For children with cerebral palsy, the COPM has been used as a measure for functional self-efficacy (Reid & Campbell, 2006). According to Reid and Campbell "theoretically, enhanced feelings of self-efficacy will in turn, result in improved perception of performance and satisfaction with performance." (2006, p. 257).

Children younger than 8 years of age are not able to answer easily in the COPM format (Missisuna, Pollock, Law, Walter, & Cavey, 2006). Additionally, according to the COPM manual, a valid responder about the client's performance can be caregivers or relatives (Law et al., 1998). Thus, mothers identified up to five concerns of their children's performance in play and its importance. Then, mothers provided information about their perceptions of the children's performance and their satisfaction with their child's performance in play through the COPM during an interview.

2.5.3. Other data collection

2.5.3.1. Mother's satisfaction with the intervention

Mothers had opinions and perceptions about the intervention. Mothers' satisfaction with the intervention was assessed through the following questions asked during an interview with the mother at the end of the intervention:

- Do you think your child enjoyed playing with the robot? Why?
- Do you think your child's play was different when he played with the robot than when he played without the robot? In what ways was it different?
- Do you think the robot is a tool that allows your child to interact with toys? Why?

- What do you think might be changed in the activity with the robot so that your child enjoys the activity more? Why?
- Has somebody who interacts with your child noticed changes in your child's play behavior since the invention started? What have they told you?

These interviews were video recorded. Since the interviews were conducted in Spanish, the researcher faced a problem that has been described by Regmi, Naidoo and Pilkington (2010) in qualitative research when investigators conduct research in a source language other than English and present findings in a different target language. In the current study, the data were gathered in Spanish and presented in English. Researchers have developed strategies in order to deal with this issue. Esposito (2001) suggests that the ideal condition is the researcher who collects data is proficient in the source language and familiar with the culture. Esposito also suggests that, in order to translate the findings from the source language to the target, the meanings should be first understood and conceptualized from the source language. Then, the meanings are translated to the target language. Based on this recommendation, for the current study the researcher first summarized the most relevant information from the interviews in the source language (Spanish). The summaries were presented to each mother in order for them to assess whether the summaries reflected accurately and completely the meaning of what was expressed during her interview. This validation with the research participants was followed by validation by a third rater. She was a master's student at the University of Alberta who was not aware of the study's purposes and who was proficient in the source language and familiar with the source culture. This rater watched the video-recorded interviews and read the summaries, assessing whether the summaries expressed accurately and completely the meaning of what was said by the mothers during the interviews. Finally, a different native English speaker who was proficient in Spanish and familiar with the Colombian culture translated the summaries to English.

Regarding the validity of the interviews, , all mothers felt that the information in the summaries reflected accurately and completely the meaning of what they expressed during the interview. The third rater confirmed that the summaries expressed accurately and completely the meaning of what was said by the mothers during the interviews.

2.5.3.2. Confounding Events

Since the dependent variables are related to play, some external life events could affect them. Each mother was asked to describe any events that were different from the usual family routines and habits and that might impact their play time. This was noted at the beginning of each session. In the same way, if the child was sick (e.g., flu) which made the child irritable or fussy, both the mother and the child were asked if they wanted to do the play session. If the mother felt particularly tired or sick, this was noted. All children experienced flu at some point of the study; however, both mother and child expressed that they wanted to do the session, and no session was cancelled after the researcher arrived in the home or rehabilitation centre. There was a major strike in the city that affected the data collection for two participants (see section 2.4 and footnote 2).

Table 2.6 Study questions, hypothesis, measures and phases

Variables	Questions	Hypotheses	Measures	Source of data	P BL	BL	I	F-U	End
Child's playfulness (DV)	**1A:** Do the ToP scores (measure of playfulness) of children with CP increase during the intervention when a robot as an augmentative manipulation device is available for free play with their mother in a natural environment compared to the baseline?	**1A:** The ToP scores (measure of playfulness) of children with CP will increase during the intervention when a robot as an augmentative manipulation device is available for free play with their mothers in a natural environment compared with the ToP scores in the baseline.	Test of Playfulness (ToP)	Child - Observation		X	X		
	1B: Is there a change in the ToP scores (measure of playfulness) of children with CP following the intervention (availability of a robot as an augmentative manipulation device for free play) in comparison with the baseline?		Test of Playfulness (ToP)	Child - Observation		X		X	
Maternal directiveness (DV)	**2A:** Does the mothers' directiveness decrease during the intervention while their children with CP are able to use a robot as an augmentative manipulation device during free play in a natural environment compared with the baseline?	**2A:** Mothers of children with CP will show significantly less directiveness during the intervention when their children are able to use a robot as an augmentative manipulation device during free play in a natural environment compared with the baseline.	Maternal Behavior Rating Scale (MBRS) Directive subscale.	Mother - Observation		X	X		
	2B: Is there a change in the mothers' directiveness following the intervention (availability of a robot as an augmentative manipulation device during play) compared with the baseline?		Maternal Behavior Rating Scale (MBRS) Directive subscale.	Mother - Observation		X		X	

Variables	Questions	Hypotheses	Measures	Source of data	P BL	BL	I	F-U	End
Maternal responsiveness (DV)	**3A:** Does the mothers' responsiveness increase during the intervention while their children with CP are able to use a robot as an augmentative manipulation device during free play in a natural environment compared with the baseline?	**3A:** Mothers of children with CP will be significantly more responsive during the intervention when their children are able to use a robot as an augmentative manipulation device during free play in a natural environment compared with the baseline.	Maternal Behavior Rating Scale (MBRS) Response subscale.	Mother - Observation		X	X		
	3B: Is there a change in the mothers' responsiveness following intervention (availability of a robot as an augmentative manipulation device during play) compared with the baseline?		Maternal Behavior Rating Scale (MBRS) Response subscale.	Mother - Observation		X		X	
Maternal Affect Animation (DV)	**4:** Is there a change in the mothers' affect/animation either during or after the intervention (availability of a robot as an augmentative manipulation device during play) compared with the baseline?		Maternal Behavior Rating Scale (MBRS) Affect/ Animation subscale.	Mother - Observation		X	X	X	
Occupational Performance (DV)	**5:** Is there a change in mother's perceptions of their child's occupational performance in play following intervention (availability of a robot as an augmentative manipulation device for free play) compared with the performance before the intervention?		Canadian Occupational Performance Measure (COPM)	Mother - Interview	X	X	X		X
Occupational Satisfaction with the performance (DV)	**6:** Is there a change in the mother's satisfaction with their child's performance in play following intervention (availability of a robot as an augmentative manipulation device for free play) compared with satisfaction before the intervention?		Canadian Occupational Performance Measure (COPM)	Mother - Interview	X	X	X		X
Family's satisfaction with the intervention	**7:** How does mother feel about the intervention?		Interview	Mother - Interview			X		

Notes:
DV: Dependent Variable, PBL: Pre baseline, BL: Baseline, TR: Training, I: Intervention, F-U: Follow-up

2.5.3.3. Test of Environmental Supportiveness (TOES)

The supportiveness of the environment for play was measured through the Test of Environmental Supportiveness (TOES) (Skard & Bundy, 2008) which assesses the extent to which characteristics of a given environment facilitate the player's motivation for playing. The TOES is an observational measure that is related to the ToP. The TOES has 17 items, which can be scored individually, but currently there is no means to aggregate them into an overall score. Items include the assessment of caregiver, peer playmates, younger playmates, older playmates, and non-human environment (amount and configuration of the space, natural/fabricated objects, space physically safe, and accessibility). Researchers have reported acceptable values of inter-rater reliability and validity for the TOES using the Rasch analysis (Skard & Bundy, 2008). The researcher used the TOES for ensuring that the characteristics of the non-human environment during the baseline, intervention and follow-up phases were the same. Nothing within the physical environment should change except for the addition of the robot. As part of the procedures for assessing the treatment integrity, the TOES items related to non-human environment were assessed for every session by watching the videos. No inter-rater reliability was done for the TOES.

2.6. Data collection

Two video cameras were located in the room in which the child-mother dyad played. One camera (Camera face) was recording the child's face and body; the second camera (Camera scenario) was recording what was happening with the toys and the robot. The Camera face was used for recording the instructions given to the mother and to the child in each session. After that, the Camera scenario was turned on. Recordings were synchronized by having a signal (a beep of the Camera scenario) to indicate the start of the session. The videos provided data for scoring the ToP, the MBRS and the TOES.

2.6.1. Study Protocol

Before the baseline started, the researcher identified characteristics of the child's play within the family environment. The characteristics identified were:

- The child and the mother selected the set of toys that were used during the study. There were up to 20 toys. Play materials such as a set of blocks were counted only as one toy. Twenty toys is the average number of toys that have been used in research on play (Gowen et al., 1992; Marfo, 1992). A list of these toys was made in order to maintain the same set of the toys during all phases of the study. Switch activated toys available at home were excluded in order to have only one kind of electric/electronic assistive technology device (the robot). The decision to use the child's toys instead of a set of standardized toys was based on an observation made by Chiarello and Palisano (1998). They indicated that providing a standardized set of toys interferes with the natural way in which the child plays because the mother feels forced to ask the child to play with all of the toys provided by researchers resulting in frequent changes of play activities.
- The play habits and frequency of the mother-child dyad engaging in play, including reading stories to the child, and watching movies or television shows together. This information was taken into account for establishing the timing of the twice per week sessions (days, time of day), maintaining the typical hours and days as much as possible.
- The child's position during play activities. The child's motor control while sitting on the floor was assessed. Additionally, the mother was asked about any conditions that could prohibit the child from sitting on the floor. The criterion for deciding the children's position was that each child should be safe and stable. As a result, the children's position varied as shown in Table 2.2. A sitter chair was provided to P01 and P02.
- The room where the child usually plays and the room where mother and child could play without any interruption from other members of the family (See Table 2.4. Participant's schedule and Locations).

2.6.2. Session protocol

Sessions were conducted twice per week. Any change in the schedule was recorded. Other members of the family or rehabilitation staff were asked to remain in a different room and remain quiet while the sessions were carried out. Each session whether baseline, intervention or follow-up was carried out according to the following guidelines:

- At the beginning of each session, the mother and the child were asked how they felt that day: good, normal or bad.
- The toy check list was reviewed.
- The child was placed on the floor using the positioning equipment with enough space to see, play and interact.
- There was a space of 3 to 4 feet between the child and the toys. This allowed enough space for the child to freely move the robot around during intervention. The toys were located next to each other so that the child could see them all.
- The same verbal instructions were provided to the child and to the mother in each session. There were two different instructions according to the study's phase:
    - For the baseline and the follow-up phase:
        - For the mother: *"Play with (child's name) as you typically do. I will not evaluate any particular skill. I only want to observe how you play. I would like you to play for 15 minutes."*
        - For the child: *"You can play with any toys that you want. Your mom will play with you."*
    - For the intervention phase:
        - For the mother: *"Play with (Child's name) as you typically do. I am not interested in observing how well (child's name) controls the robot. I will not evaluate any particular skill. I only want to observe how the robot is part of your play. I would like you to play for 15 minutes."*

- For the child: *"You can play with any toys that you want and with the robot. Your mom will play with you."*

- During the intervention the robot's programming, accuracy, infrared signals, batteries and switches were functioning appropriately. The researcher involved the children in this assessment, so the children participated evaluating if all of the robotic components were working appropriately.
- At the end of the session the researcher asked the mother about any events that had been different from the family routines and habits during the preceding days that might have had an impact on the play session.

2.6.2.1. Baseline phase

The child was seated on the floor using the sitter chair or in the chair. The chosen toys were placed visible to the child. For each session, the ToP, the MBRS and the TOES were measured.

According to Kazdin (2011) not every measure must be repeatedly administered but at least one has to be. The primary measure is the one that determines the stability of the baseline and is used to meet the design requirements (Kazdin, 2011). Additionally, for a multiple baseline design, it is recommended that "both the number of calendar days from first assessment day to intervention and the number of baseline data collection days need to be different for each participant"(R.J. Sobsey, personal communication, February, 12, 2013).

2.6.2.2. Training

Each child was trained by the researcher in the use of the switches for making the robot move and carry objects. All mothers were present during the child's training sessions. The training sessions were done according to each child's skills. Each training session was an average of 45 minutes long for P01 and P03, and 30 minutes long for P02. There was only one 30-minute session for P04. The number of sessions depended on how quickly each child reached the highest skill level (Level 4, see Table 2.7) but it did not exceed two and a half weeks. The first part of the training consisted of switch assessment where voluntary and consistent motor patterns were identified (Tash Inc., 1996). Then, the training was carried out following the first four levels of cognitive skills required for operating a robot, as presented in Table 2.7.

Table 2.7 Robot–Related Skills

Skill		Definition for robot use
1	Cause and Effect [Causality]	Understanding the relationship between a switch and a resulting effect
2	Inhibition [Negation]	An action can be negated by its opposite
3	Laterality [Binary Logic]	Two opposite effects such as on and not on
4	Sequencing [Coordination of multiple variables]	Movement in more than one dimension to meet a functional goal

Adapted from: Cook, Adams, Encarnação and Alvarez. The role of assisted manipulation in cognitive development(2012). p. 140

The training for the first three levels was based on previous studies (Cook et al., 2012; Encarnação et al., 2014; Poletz et al., 2010) as follows:

- Task 1 –cause and effect: Children were asked to press and hold a switch to make the robot move forward until it knocked over a stack of blocks (one switch).
- Task 2 –inhibition: Children were asked to stop the robot beside a pile of blocks (they did this by releasing the switch), the researcher loaded some blocks onto the robot, then the children had to stop for blocks to be unloaded at the initial stack position (one switch).
- Task 3A –Laterality: With the robot in the middle of two stacks of blocks and facing forward, children were asked to turn the robot in the appropriate direction using one of two additional switches that made the robot turn 90 degrees to face one of the stacks of blocks (two or three switches).
- Task 3B –sequencing: After turning in the appropriate direction, they were asked to press and hold the original forward switch to move towards the chosen pile of blocks (two or three switches).

As children achieved the skill for one level (3 out of 3 times, as in previous studies), they continued to the next level. For sequencing (Level 4), a protocol developed by Adams (2011) was used. Adams introduced another switch to make the robot to move backwards and used a slalom course task where the child had to coordinate multiple variables (go forward/backward, turn left/right) by navigating a slalom course with the robot. In this study neither accuracy nor time was recorded while children were trained in sequencing. The materials used were small wooden blocks, small toys, paper, pens and happy face stickers as a reward. Another activity used for sequencing was to make the robot go through an easy path drawn on a paper. The last part of the training consisted of learning the use of the robot scoop to manipulate little toys. This included catching and pushing small toys using the robot scoop and releasing them by going backwards. Table 2.8 shows the characteristics of the training for each child participant.

Table 2.8 Level of training and number of training sessions for each participant

Training level	P01 # sessions	P02 # sessions	P03 # sessions	P04 # sessions
Switch assessment	T1	T1, T2, T4, T8	T1, T2, T4	T1
Task 1 –cause and effect	T2	T3	T1	T1
Task 2 –inhibition	T2	T3	T1	T1
Task 3A –binary relations	T3	T5	T2	T1
Task 3B –sequencing	T3	T5, T6, T7, T8	T3	T1
Sequencing slalom	T3		T4	T1
Use of the robot scoop	T3, T4		T4	T1

T#=number of the training session

Each mother was trained in technical aspects for use of the robot. They learned how to turn the robot on and off, how to position the remote control in case the robot does not reach the infrared signal and, how to re-ensemble the robot's parts in case that they came apart. The training also included showing the mother that the robot was not extremely delicate but it tolerated bumping into objects, the edge of the board, furniture or the wall. Since none of the mothers were familiar with switches, the training included showing them that the switches tolerated being hit with considerable force by the child and how to re-position the mounted equipment in case it changed its initial position during the session. Once the mother had been trained and her child was able to operate the robot, the intervention phase began.

2.6.2.3. Intervention phase

During the intervention sessions, the environmental setting and conditions were the same as during the baseline for each mother-child dyad. The only difference was that each child was able to operate the robot independently and the robot was available during free play. P01 and P02 used the robot on the floor while P03 and P04 used the robot on a wooden board with 5 cm-high walls along the edges. The boards were located on a bed for P03 and on the dining table for P04. For each session the ToP, the MBRS, and the TOES, were scored. The COPM was administered at the end of the intervention. The interview about the mother's satisfaction with the intervention was administered at the end of the intervention.

2.6.2.4. Follow-up phase

The objective of the follow-up phase was to identify the presence of changes in the dependent variables that persisted after the intervention. The follow-up had three sessions separated from the day in which the intervention finished as follows: For P01 the follow-up sessions were conducted 5, 14 and 33 days after the intervention finished; for P02 they were 3,17 and 31 days; for P03 they were 7, 21 and 31 days; and for P04 they were 3, 16 and 30 days. In the follow up phase the measures scored were the ToP, MBRS and COPM (see Table 2.6). ToP and MBRS were scored for each session. The COPM was administered for the final time at the end of the follow-up period.

2.6.3. Treatment Integrity

Treatment integrity was achieved through strict adherence to the protocol during every session considering Gresham's (1996) verbal, physical, temporal and spatial parameters. A treatment protocol checklist was developed in order to assess the adherence to the protocol (see Appendix H). The researcher checked the protocol at the beginning and at the end of each session and also noted any event that happened during the session such as a noisy environment, the telephone rang, or a relative interrupted the session. In addition to the check list, the characteristics of the environment related to the factors that could affect playfulness were assessed through the TOES after each session by watching the video. The following rules for the assessment of the treatment integrity for the time were used. If the session started up to 60 minutes after the hour of the appointment, the time was checked as being the same time as arranged. This length was chosen because there was always time between the researcher's arrival at the participant's home, and the actual start of the session. In addition to the researcher checks, two different raters who were proficient in Spanish and English assessed the treatment integrity in 20 sessions (Appendix I). The randomly selected sessions for their assessment corresponded with 32.9% of the baseline sessions, 20% of the intervention sessions, and 33.3% the follow-up sessions. For assessing the treatment integrity, the two external raters used the videos, and the treatment integrity check list and notes taken by the researcher for the selected sessions.

2.7. Analysis

Data were evaluated according to the guidelines for single-case design research using both experimental and applied criteria. The experimental criterion is related to the reliability of the results. A reliable change should be an effect of the intervention rather than due to pre-existing patterns, normal fluctuations or chance (Kazdin, 2011). Kazdin (2011) strongly recommends examining the different characteristics (i.e. changes in levels, trends, latency and overall pattern or overlap) of the data separately through visual inspection and then statistical analysis in order to reduce the probability of committing Type I or Type II errors. Kratochwill and colleagues (2010) suggest six features to examine both within- and between-phase data patterns: level, trend, variability, immediacy of the effect, overlap, and consistency of data patterns across similar phases. In this study visual inspection of these six characteristics was performed and followed by a statistical analysis when applicable. The applied criterion refers to whether the effects of the intervention are so large as to make a genuine difference that positively affects the individual's life (Kazdin, 2011); this criterion was assessed through the clinical significance and social validation of the change. Social validation refers to how the client and others would see that the change positively affects the individual's life. All of the statistical analyses were calculated using Microsoft Excel 2010.

There are two problems that can affect both visual and statistical analysis in single case design: a baseline that does not show stability (Kazdin, 2011) and serial dependence in the data (Matyas & Greenwood, 1996). Thus, both stability of the baselines and serial dependence of the data were assessed. The ToP raw score was chosen as the measure for determining the stability of the baseline. The stability of the baseline was assessed through visual analysis and confirmed using the X-moving range chart technique once each participant reached the fifth session (Orma & Cox, 2001). This technique is part of the statistical process that has been applied to single-case design research. According to this technique, both upper control limits (UCL) and lower control limits (LCL) are plotted at 3 standard deviation above and below the mean. If data is stable, all data points should fall within the control limits (Orma & Cox, 2001; Portney & Watkins, 2008). The stability of the baseline was assessed again once the Rasch ToP scores were available in order to confirm the baselines were still stable using the Rasch scores. The stability of the baseline was also assessed for the MBRS scores.

The serial dependence of the data was assessed by running a lag-1 autocorrelation for the series of data at baseline and intervention. In doing so, a procedure described by Ottenbacher (1986) was used for calculating the autocorrelation coefficient (r). According to this procedure if the lag-1 autocorrelation for a series of measures is statistically significant ($p<0.05$), the scores are serially dependent. For determining whether the autocorrelation coefficient was statistically significant or not, a procedure called the Barlett's test was used. If the autocorrelation coefficient was greater than $\frac{2}{\sqrt{n}}$ where n was the number of data points in the phase, the autocorrelation coefficient was considered significant (Ottenbacher K. , 1986). For this study, the autocorrelation coefficients were compared with $\frac{2}{\sqrt{n}}$ where n=8 at the baseline for P01 and MP01; n=5 at the baseline for P02 and MP02; and, n=6 at the baseline for P03, MP03, P04 and MP04. For all of the participants n=10 at the intervention. If there were no significant autocorrelations, then comparisons between phases could be performed. If the scores were autocorrelated, then a transformation of scores would be performed according to the procedure by Ottenbacher (1986) that was used by Brien and Sveistrup (2011).

2.7.1. Analysis for comparing the phases

For comparing data at baseline, intervention and follow-up phases, the Rasch ToP scores and the average of each subscale of the MBRS were graphed using a simple line graph. Level, variability, latency, overlap and consistency of data were analyzed for all the phases. The effect size was calculated for both intervention and follow-up phases.

Levels were compared for all the phases through visual analysis with the mean values at each phase compared with the other phases. The significance in levels was examined by using the two standard deviation band method (2SD). The significance of the change was established as at least two consecutive data points of the intervention phase and the follow-up phase falling outside the two standard deviation band calculated with the baseline data (Portney & Watkins, 2000, p. 257). In addition to the evaluation conducted using the 2SD deviation band method and to minimize the probability of committing a Type I error (0.26%), the X-moving range chart was used to compare the ToP scores at baseline, intervention and follow-up phases. Limits were plotted at ±3-standard deviation (3SD) band from the baseline's mean. To ensure that change across phases was not due to chance, the following rules were applied to the intervention and follow up scores: 1) any one point falls outside of the upper (mean +3SD) or lower limits (mean -3SD); 2) seven or more consecutive points all above or below the center mean line; or, 3) six or more consecutive points moving up or down across the center mean line (Portney & Watkins, 2008, p. 266). The upper and lower limits were calculated according to Orma and Cox (2001). This method was also used as the measure for the variability of data at the baseline.

Although the general guidelines for single case design state that only the data from adjacent phases are compared (Kazdin, 2011; Logan et al., 2008; Portney & Watkins, 2000), recent studies in rehabilitation have compared the baseline with a follow-up phase through the two standard deviation band method (Araujo Costa, 2011; Brien & Sveistrup, 2011; Øygard, Hæstad, & Jørgensen, 2011). Thus, the comparison of the baseline with the follow-up phase was performed through the two standard deviation band method for determining carry over effects after the intervention finished.

Latency was described by comparing the value of the dependent variables (ToP and MBRS) at the last data point of one phase with its value at the first data point of the next adjacent phase (Portney & Watkins, 2008). Latency provides information about the period between the termination of the one phase and the change demonstrated by the dependent variable during the adjacent phase (e.g. baseline/intervention and intervention/follow-up). The latency provides information about the effect of the intervention (Kazdin, 2011).

Trends were described for all of the phases through visual analysis. If the data showed a linear trend, the celeration line approach was used to compare the baseline with the intervention phases, according to the procedure described by Portney and Watkins (2008). Since the data in the intervention for P04 showed a nonlinear trend, a method called the resistant trend line was used to estimate the trend as recommended by Ottenbacher (1992). Slopes for both the baseline and the intervention were calculated using the celeration line or resistant trend line as applicable for each phase according to Ottenbacher (1992). For doing this, estimations of the slope were made using the scores of two sessions spaced one week apart using the equation:

$$m= \frac{\Delta y}{\Delta x}$$

The first session for slope estimation was randomly selected; the second was the session that was conducted one week later.

When baselines showed an increasing trend for playfulness or maternal responsiveness, or a decreasing trend for maternal directiveness, trend between the baseline and the intervention was assessed using the probability table developed by Bloom (as cited in Ottenbacher, 1986). This table is used for assessing whether or not the change in trend during a treatment was statistically significant based on the number of data points at the intervention in relation with the proportion of data points above and below of the celeration line at the baseline (50% is expected). Considering that all of the participants received ten intervention sessions and according to Bloom's criterion, a change in the trend was stated as statistically significant if at least nine data points of the intervention fell above (for child's playfulness and mother's responsiveness) or below (for maternal directiveness) the extension of the celeration line computed with the baseline data.

In addition, for P01 and MP01 who had eight data points during the baseline, it was possible to apply the C statistic for assessing changes in trend between the baseline and the intervention. The C statistic was calculated following the procedure in Portney and Watkins (2008). This procedure includes the calculation of a z value. The criterion to determine if there was a significant trend in the assessed phase is that the z value is greater or equal to1.645.

Overlap was visually analysed by calculating the proportion of data from one phase that overlaps with data from the previous phase (Kratochwill, et al., 2010). Finally, consistence of the pattern was examined by analyzing data from all the baselines, intervention and follow-up phases for all of the participants. This characteristic of the data was reported as the extent to which there was consistency in the data patterns from phases with the same conditions; for example, how many participants showed significant changes. The evidence provided by the study was assessed according to the rules of evidence for single-case design (Kratochwill, et al., 2010). Strong evidence is at least three demonstrations of the intervention effect along with no non-effects; moderate evidence is three demonstrations of an effect and at least one demonstration of a non-effect; and non-effect is failure of the study to provide three demonstrations of the effect on the dependent variable.

If the study provided either strong or moderate evidence for one dependent variable, then the effect size was calculated (Kratochwill, et al., 2010). The effect size was calculated using the Improvement Rate Difference (IRD). The IRD is easy to interpret and is widely used in medical literature under the name of risk reduction or risk difference (Parker, et al., 2009). IRD was calculated as the improvement rate (IR) of the intervention (I) phase minus the IR of the baseline (B) phase:

$$IRD = IR_I - IR_B$$

The IR for each phase is defined by the number of improved data points. An improved data point at the baseline is any data point that exceeds all data points at the intervention. An improved data point at the intervention is any data point that exceeds all data points at the baseline. The IR for each phase was calculated as follows (Parker, et al., 2009):

$$IR = \frac{\#\ improved\ data\ points}{\#\ total\ data\ points}$$

The benchmarks for the effect size were: very small effect <0.50; moderate effect 0.50-0.70; and very large effect >0.70 (Parker, et al., 2009).

2.7.2. Clinical significance and social validation of the change

In this study the change was clinically significant if the scores of the dependent variables fall outside three standard deviation bands in the expected direction from the mean at the baseline as suggested by Kazdin (2011). In addition, the ToP scores were assessed under the criterion of "normative comparison". The participant's performance was evaluated in relation to a normative sample (Kazdin, 2011). The normative sample of comparison was the ToP large data base composed mostly of typically developing children's scores (Bundy, 2010). Based on the ToP normative sample, ToP scores in the negative direction from zero indicated that the participant was not expressing playfulness, and scores in the positive direction from zero indicated that the participant was expressing playfulness during the session (Bundy, et al., 2001; Rigby & Gaik, 2007).

The social validation of the results was established through several ways. First, the follow-up phase provided information about carry over in the dependent variables after the intervention was stopped. In other words, how the robotic intervention impacted the child's play experience and the mother's interactive behavior up to one month after the intervention finished was examined. Second, the social validation for the performance and the satisfaction with the performance in play was evaluated through *subjective evaluation* (Kazdin, 2011) by completing the COPM. Both quantitative and descriptive information from each application of the COPM was used to describe the subjective evaluation of the change as perceived by the mothers. Third, the mother's satisfaction with the intervention in the interview was another source of social validation.

3. RESULTS

It was hypothesized that a robotic intervention would increase playfulness in children with severe motor impairment due to a diagnosis of cerebral palsy, would increase maternal responsiveness, and would decrease maternal directiveness in their mothers during free play at home.

The first section of this chapter is composed of the results of the preliminary pilot study followed by the results of the main study in a second section. This second section begins with the presentation of the overall results of the inter-rater reliability of the ToP and the MBRS measures, followed by the validation of the information in the summaries of the interviews about the family satisfaction with the intervention. Then, the results regarding the treatment integrity are described followed by the results of the analysis of the baseline stability and serial dependence. In concordance with the study's hypotheses the third section of this chapter is composed of results for children's playfulness, maternal responsiveness, and maternal directiveness. In addition, results regarding the maternal affect/animation subscale are presented. The clinical and social significance of the results are described at the end of this chapter.

3.1. Pilot study

The pilot study provided direction for the study and identified the following issues:

- The instructions to the mother during the intervention were not clear so she wondered if they were expected to include the robot in their play. Thus, a phrase related to the robot and the play session was added to the instructions during the intervention sessions: "I only want to observe how the robot is part of your play."
- The presence of the researcher video recording the sessions influenced the child's behavior. Thus, it was decided that the researcher would stay in a different room during the sessions for the main study.
- The researcher felt that scoring playfulness in the same order sessions occurred might affect the scores as the researcher remembered what had happened in the previous sessions. Thus, sessions were scored in as random an order as possible for the main study.

- During the training sessions, the participant showed difficulties engaging in the robotic tasks. She required lots of prompting for achieving the robot cognitive skills. The highest robotic skill level the girl achieved was inhibition (see Table 2.7). Operating the robot demanded cognitive skills that could be excessive for a child as young as 4 years old with a cognitive delay (PTI-2 cognitive age was lower than 3 years). Therefore, participants in the main study needed to have a cognitive age of 3 years or more.
- Assessment of the entire characteristic in the data: baseline stability, autocorrelation of data, levels, trends, and latency was required. Knowing these patterns is critical to make comparisons between phases clear. For example in the pilot, the visual analysis of the data indicated that the raw ToP scores increased during the intervention (mean= -0.1) compared with the baseline (mean= -0.4), but the difference was small. Two consecutive data points fell outside the 2SD band which indicated that the child's playfulness demonstrated significant improvement. However, this result should be analysed with caution because: 1) the participant did not use the robot during the entire session; 2) there were few data points in each phase and, 3) since other characteristics of the data were not examined (i.e. baseline stability, autocorrelation of data, trends, and latency), these patterns are not known for making clear comparisons. The significance of the results may be due to an accelerating trend in the baseline that continued during the intervention rather than because of the robot intervention. This might result in committing a Type I error.

3.2. Main study

3.2.1. Treatment integrity

Treatment integrity was high ranging between 91.27 % and 100% for all participants across baseline, intervention and follow-up sessions. Treatment integrity results by participant are summarized in Table 3.1.

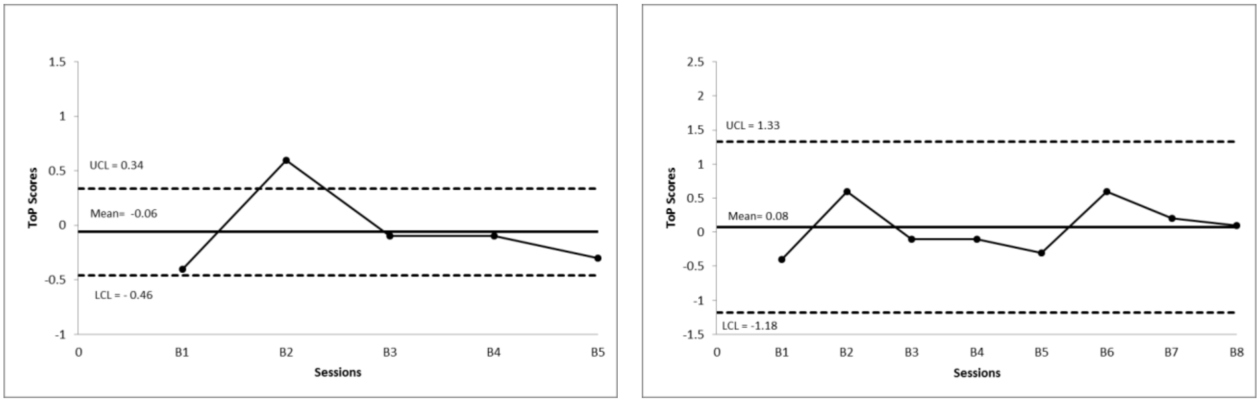
Table 3.1 Treatment integrity by each mother-child dyad

Mother-child dyad	Treatment integrity percentage - Researcher assessment	Treatment integrity percentage - Second rater assessment	Reasons for lack of treatment integrity
P01 and MP01	98.45	98.89	One toy not available in one session. Four sessions were conducted on a different day from what was arranged. One session was not conducted at the arranged time.
P02 and MP02	98.26	100	Intercom doorbell rang in three sessions. Robot had weak IR in one session A relative entered the play area One toy not available in one session One session was not conducted at the arranged time
P03 and MP03	98.68	97.78	A relative interrupted the session for few seconds Robot had weak IR Two sessions were not conducted at the arranged time
P04 and MP04	99.21	91.27	One session was conducted on a different day from what was arranged Two sessions were not conducted at the arranged time
Total	98.58	97.13	

The TOES was applied as part of the treatment integrity assessment. The TOES results revealed that the sensory environment and the amount of configuration of space were the same during the whole study; and the space where the study was conducted was safe in every session. The TOES revealed that two environmental characteristics changed during the intervention because of the implementation of the robot, the switches and the mounted equipment: 1) The natural/fabricated objects supported activity of player; and, 2) the space is accessible.

3.2.2. Baseline stability

All of the baselines of each participant for the ToP Rasch scores and MBRS scores were stable. When assessing the stability of the ToP scores for deciding the length of the baseline, all of the participants' baselines were stable at the fifth session except that for P01. P01's baseline reached stability at the eighth session (See Figure 3.1).



A B

Figure 3.1 Baseline stability ToP scores for P01.
A. Baseline stability analysis of raw ToP scores at the fifth session. B. Baseline stability raw ToP scores at session eight.
UCL: Upper Control Limits (+3-SD).
LCL: Lower Control Limits (-3-SD).

3.2.3. Data autocorrelation

Autocorrelation was assessed for the baseline and the intervention phases. No evidence of a significant correlation was found for any of the measures in any of the two phases. Table 3.2 shows the autocorrelation coefficients together with the statistical value for the Barlett's test for each participant, measure and phase.

Table 3.2 Autocorrelation analysis of the MBRS data for the baseline and the intervention sessions

Particip.	Measure	Phase	n	Autocorrelation coefficient	$\frac{2}{\sqrt{n}}$	Significant[5] degree of autocorrelation
P01	ToP	Baseline	8	0.16	0.71	No
		Intervention	10	0.24	0.63	No
MP01	MBRS	Baseline	8	R= 0.13, D=0.16, AA=0.02	0.71	No
		Intervention	10	R=0.28, D=0.02, AA=0.07	0.63	No
P02	ToP	Baseline	5	0.47	0.90	No
		Intervention	10	0.30	0.63	No
MP02	MBRS	Baseline	5	R=0.33 , D=0.00, AA= 0.23	0.90	No
		Intervention	10	R= 0.29 , D= 0.26, AA=0.17	0.63	No
P03	ToP	Baseline	6	0.33	0.82	No
		Intervention	10	0.22	0.63	No
MP03	MBRS	Baseline	6	R=0.23 , D=0.00, AA=0.15	0.82	No
		Intervention	10	R= 0.05, D= 0.26, AA=0.30	0.63	No
P04	ToP	Baseline	6	0.17	0.82	No
		Intervention	10	0.21	0.63	No
MP04	MBRS	Baseline	6	R=0.33 , D=0.24, AA=0.29	0.82	No
		Intervention	10	R=0.05 , D=0.18, AA=0.24	0.63	No
Notes: R= Responsive subscale, D= Directive subscale, AA=Affect/Animation subscale						

3.2.4. Children's playfulness

The Rasch analysis provided an overall Rasch ToP score for each session. These overall Rasch scores were plotted for each participant for each phase (see Figure 3.2- 3.5). A further analysis of the items of interest for each element of playfulness was done using the raw ToP scores and is presented in the discussion section. A visual analysis revealed clear changes in the intervention compared with the baseline. Table 3.3 shows the mean values for each participant at each phase. The mean ToP score for the intervention phase was larger than that at baseline for all of the children. The mean ToP score at follow-up was greater than the mean score at intervention only for P01. For P02, P03 and P04 the level of playfulness decreased at follow-up. For P01, ToP scores at follow-up were greater than both intervention and baseline.

[5] Significant degree of autocorrelation if the autocorrelation coefficient > 2/√n.

Table 3.3 Participants' ToP mean and standard deviation (SD) scores at baseline, intervention and follow-up phases

Participant/Phase	Mean baseline (SD)	Mean intervention (SD)	Mean follow-up (SD)
P01	-0.18 (0.32)	1.62 (0.99)	2.1 (0.71)
P02	-1.56 (0.14)	-0.053 (0.38)	-0.88 (0.30)
P03	-1.26 (0.08)	1.325 (0.75)	-0.15 (0.32)
P04	0.39 (0.27)	1.82 (0.44)	0.79 (0.21)

Regarding latency, graphs revealed that once the intervention began, the level of playfulness immediately improved for participants P02, P03 and P04. This plot shows that P01's playfulness did not change immediately after the intervention started; the ToP scores were higher than those at the baseline by intervention session I4.

Statistical comparisons using the 2SD and X-moving range chart methods revealed that all the children's playfulness increased significantly while they played with the robot. When comparing the baseline with the follow-up phase using the same methods, retention of improvement in level of playfulness was observed for P01, P02, and P03 but not for P04. Figures 3.2 to 3.5 display the 3-standard deviation band calculated using the X-moving range chart method for all of the participants. It can be also seen in these graphs that all the baselines were stable when intervention was implemented.

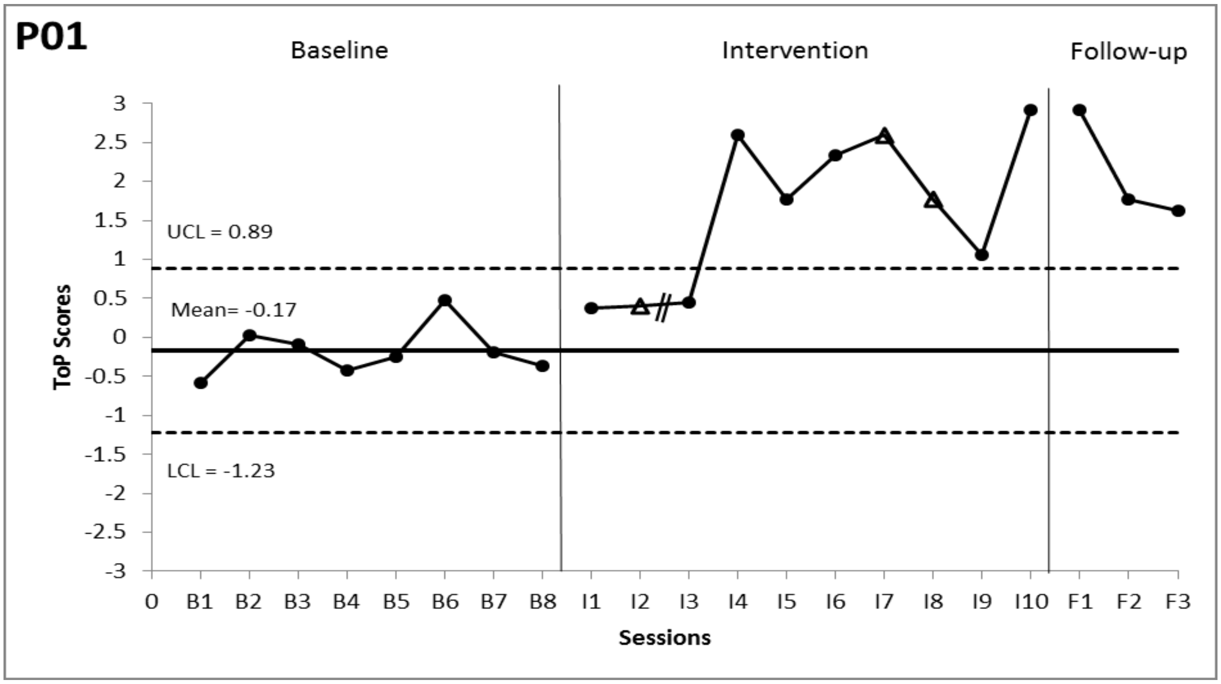


Figure 3.2 Comparison of ToP scores at baseline, intervention and follow-up phases forP01 using X-moving range chart.
UCL: Upper Control Limits (+3-SD). LCL: Lower Control Limits (-3-SD).
// = two sessions missed. Δ= P01 used the robot for only part of the session

During the intervention P01 used the robot for only part of three sessions. In session I2, P01 did not incorporate the robot in his play between minutes nine to ten or between minutes fourteen to fifteen, resulting in play with the robot during 74.2% of the session. During this time P01 did not play with anything else. In session I7 at the tenth minute of the session, P01 stopped using the robot and asked his mother to get him off of the chair and "play karate" with him. In this session the robot was incorporated in his play during 64.3% of the session. His mother lifted him off of the chair and moved him out of the range of the two cameras. Thus, the ToP was scored in this session using only the initial eleven minutes that were within the camera range. In session I8, P01 stopped using the robot at minute eleven and asked his mother to play with a toy piano and a box lid. He played with these toys until the end of the session. In this session the robot was part of P01's play for 71% of the entire session.

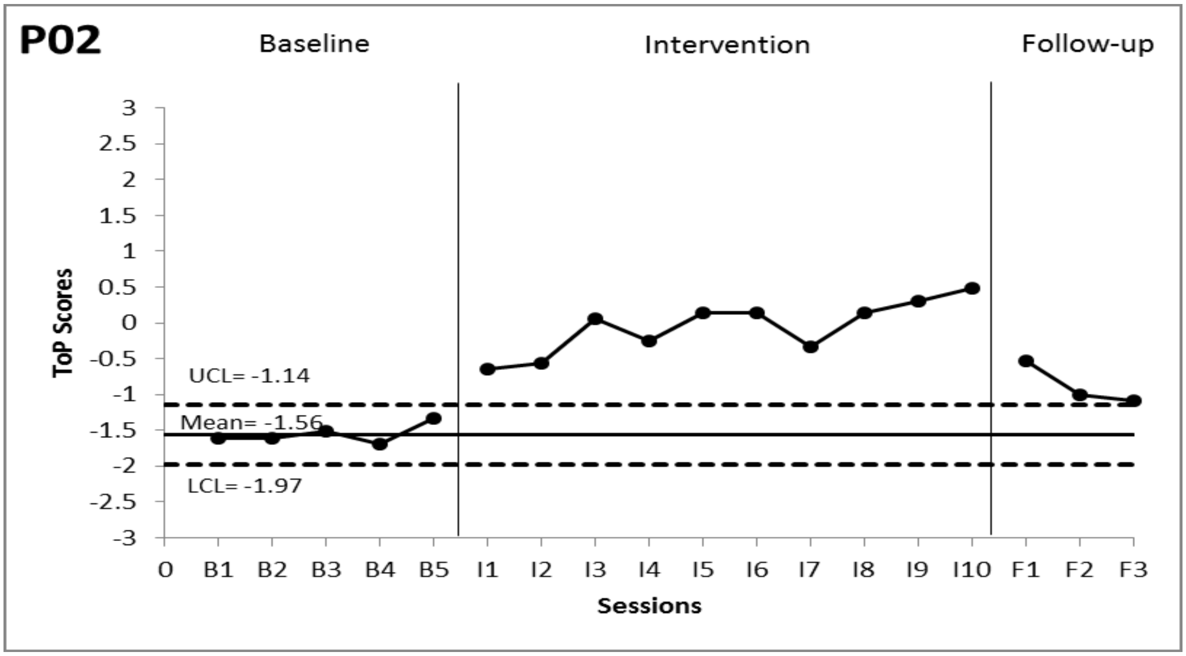


Figure 3.3 Comparison of ToP scores at baseline, intervention and follow-up phases for P02 using X-moving range chart. UCL: Upper Control Limits (+3-SD). LCL: Lower Control Limits (-3-SD).

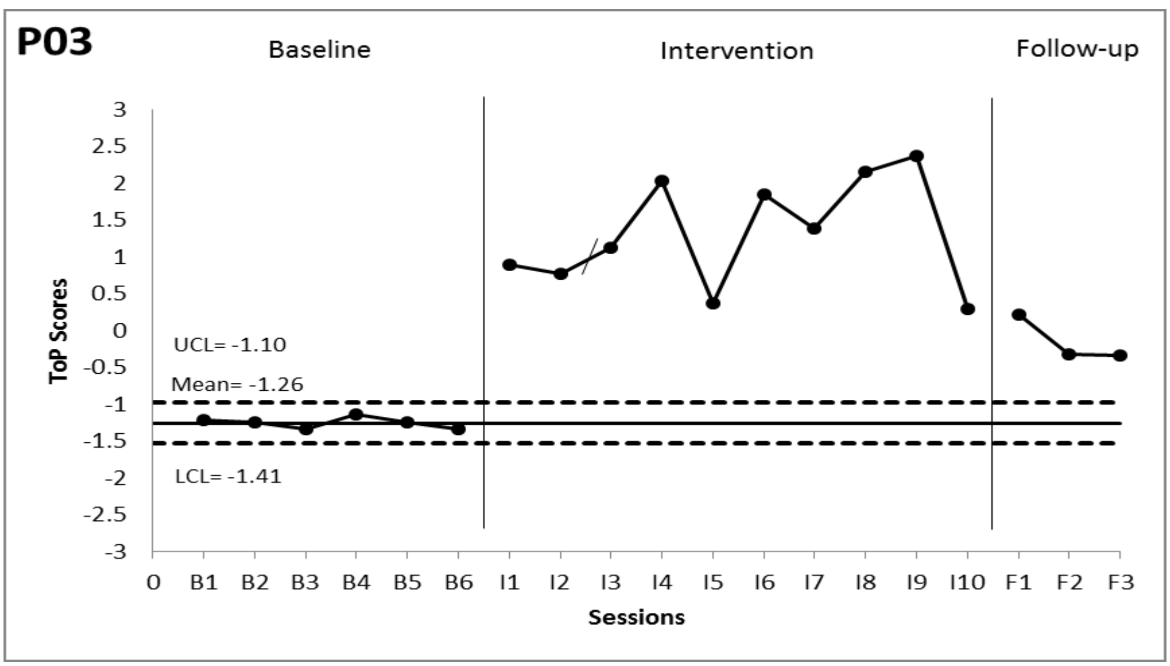


Figure 3.4 Comparison of ToP scores at baseline, intervention and follow-up phases for P03 using X-moving range chart. UCL: Upper Control Limits (+3-SD). LCL: Lower Control Limits (-3-SD).
/ = one session missed

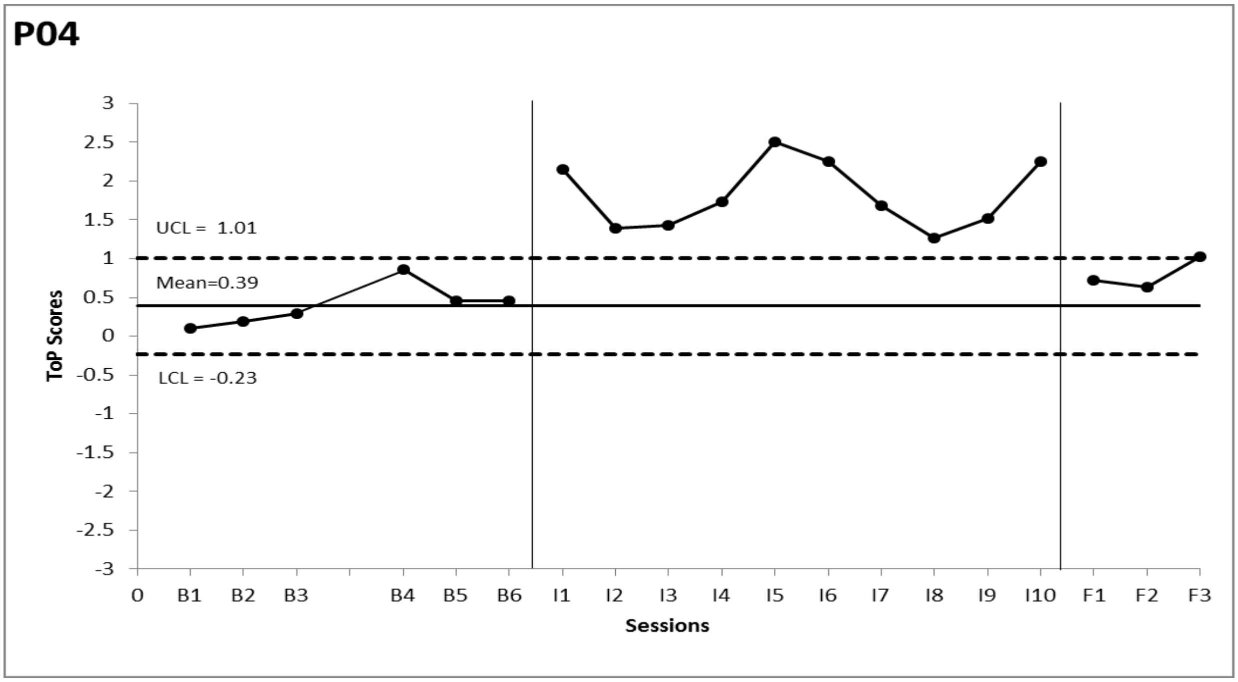


Figure 3.5 Comparison of ToP scores at baseline, intervention and follow-up phases for P04 using X-moving range chart. UCL: Upper Control Limits (+3-SD). LCL: Lower Control Limits (-3-SD).

Visual analysis of trends revealed that there were no evident trends in the baselines for P01, P02 and P03. There was a slight accelerating trend in P04's baseline. During the intervention all children's ToP scores showed an accelerating trend. The slope of the baselines (BL) and interventions (I) estimated from the trend lines were: BL=0.06, I= 0.8 for P01; BL=0.04, I= 0.18 for P02; BL=0, I= 0.39 for P03; and BL=0.13, I=0.03 for P04. A decelerating trend was observed during the follow-up for all the participants except for P04 whose data at follow-up showed an accelerating trend. The C statistic calculated for P01 revealed that there was not a significant trend at baseline (C= -0.03, SE=0.31, z=-0.10, p value = 0.92). However, when combining the scores for the baseline and the intervention, the C statistic revealed that there was a significant trend (C=0.74, SE=0.22, z=3.33, p value=0.00). This indicates that there was a significant improvement in the trend of P01's playfulness once the intervention was implemented compared with the baseline.

Since P04 demonstrated an accelerating trend during the baseline, the baseline was extended to the intervention in order to visually compare the trend of data across these two phases. The celeration line approach in Figure 3.6 shows the celeration line of the baseline (solid line) extended into the intervention phase (dashed line). All of the data points in the intervention phase fell above the extended celeration line demonstrating, according to Bloom's criterion, that the change observed during the intervention was statistically significant (p value< 0.05).

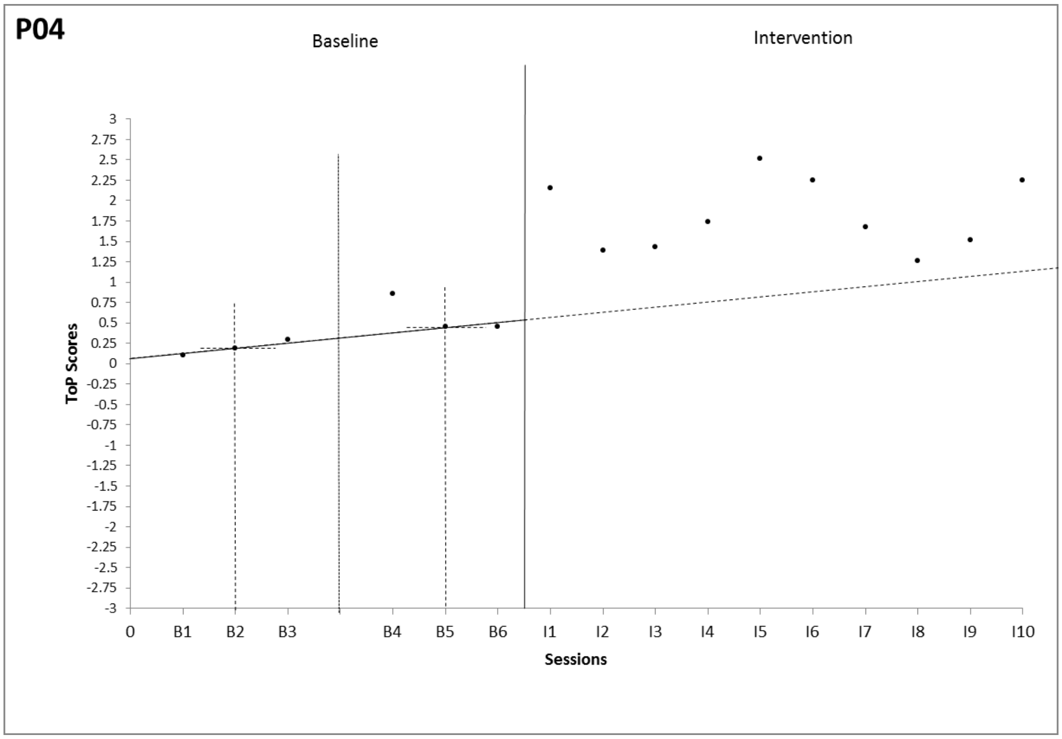


Figure 3.6 Celeration line computed for the P04's ToP scores at baseline phase and extended to the intervention phase.

The visual analysis also revealed that the proportion of ToP scores at baseline that overlapped with those at the intervention was very low. It was 30% (first three scores) for P01, and 0% for P02, P03 and P04. The level of most of the scores at intervention was much greater than at the baseline.

In summary, playfulness significantly increased during the intervention in all four participants. Since the intervention had a strong effect on children's playfulness, effect size was calculated. The Improvement Rate Difference (IRD) for each participant was: P01=0.58 (58%); P02=1 (100%); P03=1 (100%); and P04=1 (100%). This indicates that the magnitude of the effect was large for three children and moderate for one. The average of the effect sizes indicated that the whole study had an effect size of 0.90 or 90% which is a very large effect.

Although not hypothesized, the results suggest that there was retention in the increased level of playfulness of children with cerebral palsy following the robotic intervention. In this case, there were carry over effects in three out of four children.

Results regarding how data fit the expectations of the Rasch model revealed that 87% of data was within the acceptable limits of the Rasch model. About 50% of the sessions that were not within the accepted ranges were baseline sessions, three were follow-up sessions (P01's follow-up sessions), and two were intervention sessions (both of them P04).

3.2.5. Maternal directiveness

Table 3.4 shows the mean values for each participant at each phase. Average scores on the maternal directive subscale were plotted for each participant for each phase in Figures 3.7 to 3.10. Maternal directiveness decreased during the intervention in all of the mothers. This change was clearer in those mothers who had high scores during the baseline (MP02 and MP03). During all follow-up phases, all mothers showed smaller means in directiveness than during the baseline. However, MP02's two last directive scores at follow-up reverted back to the baseline level. Maternal directiveness was greater during the follow-up than during the intervention for three mothers (MP01, MP02,03) while MP04 showed less directiveness during the follow-up than when her son was playing with the robot.

Table 3.4 Maternal directiveness means and standard deviation (SD) at baseline, intervention and follow-up phases

Participant/Phase	Mean baseline (SD)	Mean intervention (SD)	Mean follow-up (SD)
MP01	2.94 (0.18)	2.20 (0.26)	2.50 (0.00)
MP02	4.50 (0.00)	2.90 (0.21)	4.17 (0.58)
MP03	5.00 (0.00)	3.25 (0.49)	3.83 (0.00)
MP04	2.92 (0.49)	2.60 (0.32)	2.50 (0.00)

Regarding latency, the graphs reveal that once the intervention began, maternal directiveness immediately decreased for participants MP01, MP02 and MP03. MP04's directiveness dropped before the intervention began; thus, it is not clear if the maternal directiveness dropped because of the intervention or confounding factors.

Statistical comparisons using the 2SD and X-moving range chart methods revealed that mother's directiveness decreased significantly for MP01, MP02 and MP03 during the intervention but not for MP04. When comparing the baseline with the follow-up phase using the same methods, the decrease on maternal directiveness was retained only for MP01 and MP03. Figures 3.7 and 3.10 display the 3-standard deviation band calculated using the X-moving range chart method for MP01 and MP04. Since MP02 and MP03 had the same score in all of the baseline sessions, the variance was zero; thus, both the 2SD and 3SD bands have the same value as the baseline mean which is plotted as a dashed line (Figures 3.8 and 3.9). For MP02 and MP03 the displayed graphs are also showing the difference in mean levels and values at each phase. It can be also seen in these graphs that all the baselines were stable when intervention was implemented.

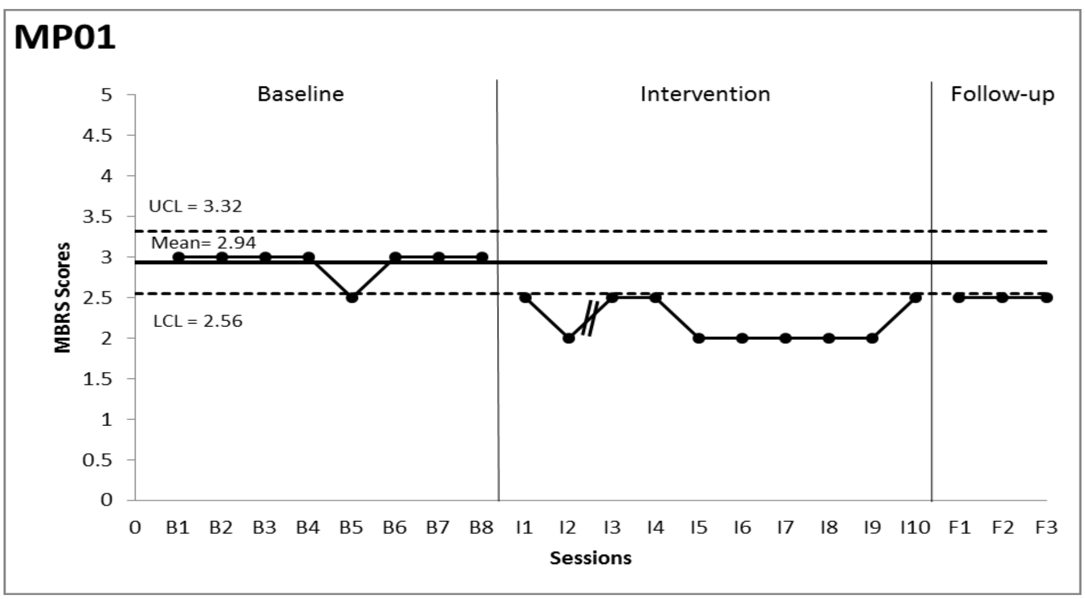


Figure 3.7 Comparison of subscale Directive scores at baseline, intervention and follow-up phases for MP01 using X-moving range chart.
UCL: Upper Control Limits (+3-SD). LCL: Lower Control Limits (-3-SD).
// = two sessions missed

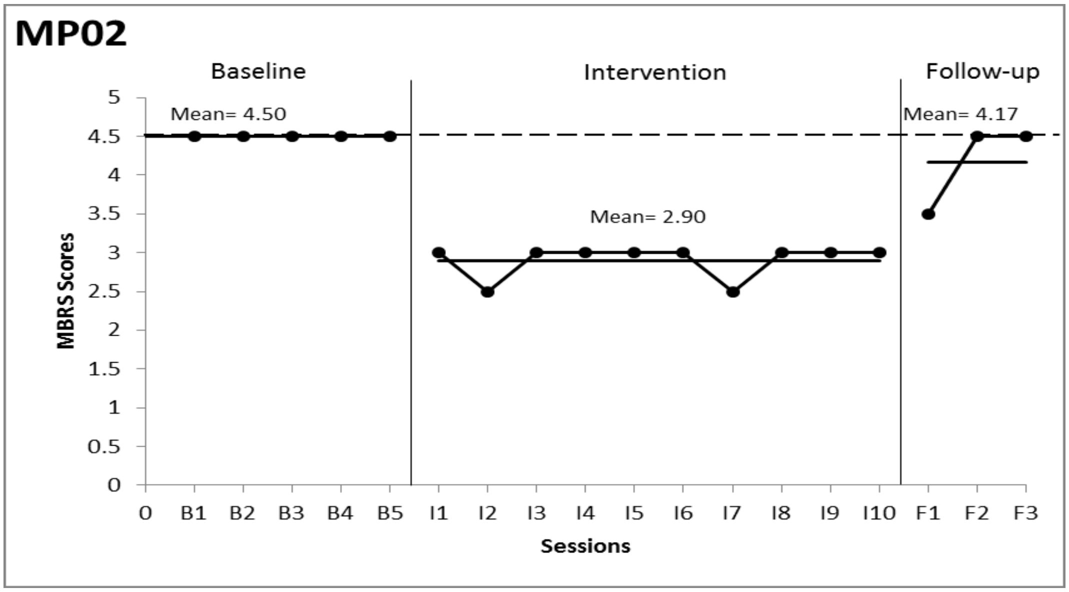


Figure 3.8 Comparison of subscale Directive scores at baseline, intervention and follow-up phases for MP02 using X-moving range chart. The UCL: Upper Control Limits (+3-SD) and LCL: Lower Control Limits (-3-SD) are represented by a dashed line.

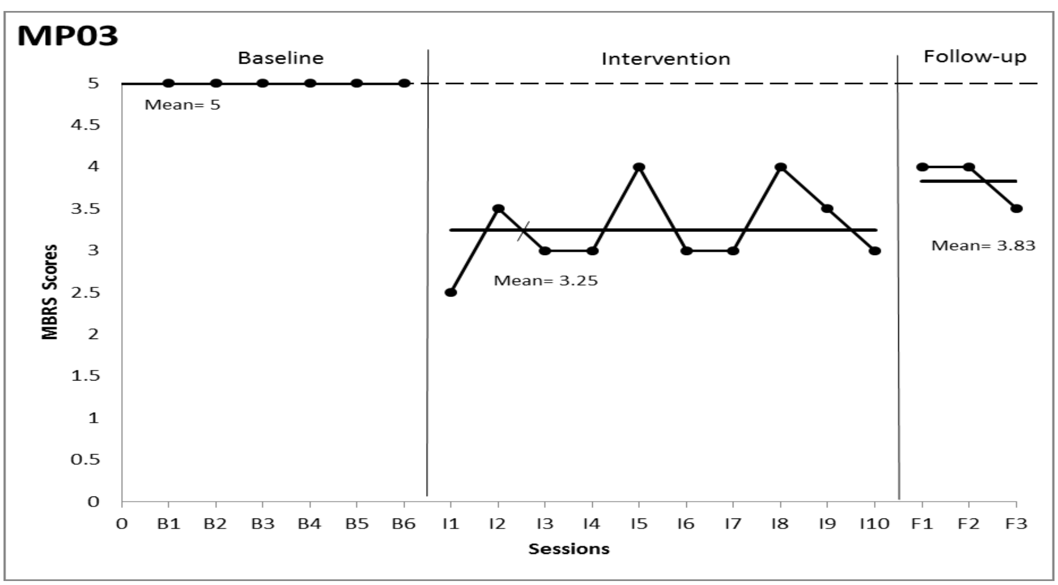


Figure 3.9 Comparison of subscale Directive scores at baseline, intervention and follow-up phases for MP03 using X-moving range chart. The UCL: Upper Control Limits (+3-SD) and LCL: Lower Control Limits (-3-SD) are represented by a dashed line.

/ = one session missed

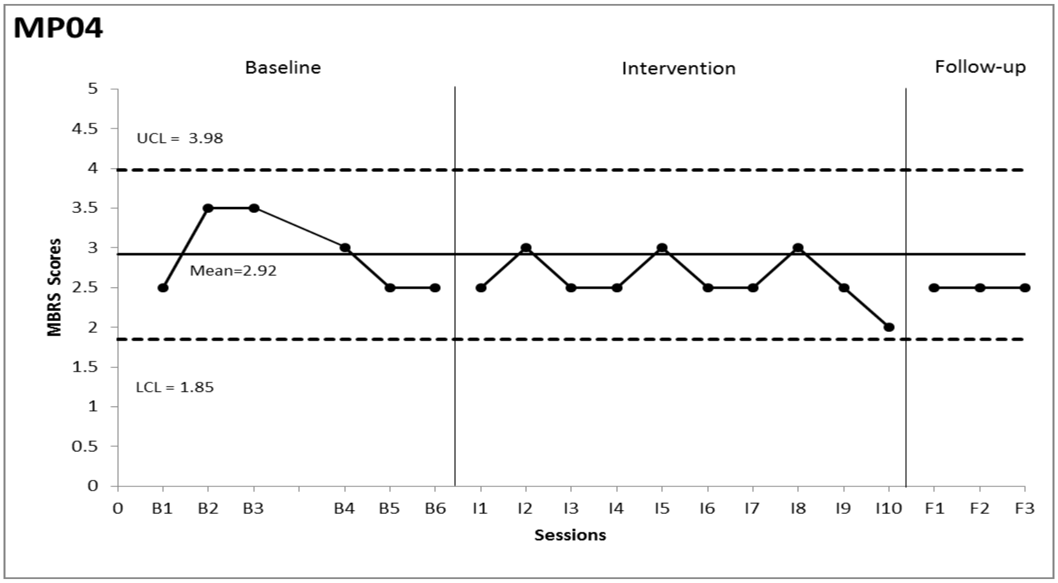


Figure 3.10 Comparison of subscale Directive scores at baseline, intervention and follow-up phases for MP04 using X-moving range chart.
UCL: Upper Control Limits (+3-SD). LCL: Lower Control Limits (-3-SD).

Visual analysis of trends revealed that there were no evident trends at baseline for MP01, MP02 and MP03; and there was a decelerating trend in MP04's scores. During the intervention there was no trend for MP02, MP03 and MP04 while MP01's scores showed a decelerating trend. The slope of the baselines (BL) and interventions (I) estimated from the celeration lines were: BL=0.00, I= -0.20 for MP01; BL= 0.00, I= 0.00 for MP02; BL=0.00, I= 0.00 for MP03; and BL= -0.5, I= 0.00 for MP04. The C statistic calculated for MP01 revealed that there was no significant trend for the baseline (C= -0.14, SE=0.31, z= -0.46, p value=0.64). In contrast, there was a significant trend for the combination of the baseline and the intervention scores (C=0.73, SE=0.22, z=3.28, p value=0.001). This indicates that there was a significant decrease in the trend of MP01's directiveness once the intervention was implemented compared with the baseline. There was no trend during the follow-up for MP01and MP04 while MP03 showed a decelerating trend and MP02 an accelerating trend during this phase.

The visual analysis also revealed that the proportion of directive sub-scale scores at the baseline that overlap with those at the intervention were 40% for MP01, 0% for MP02 and MP03; and 90% for MP04. This indicated that the level of directiveness at the intervention was smaller than those at the baseline only in the mothers who had high scores during the baseline.

In summary, maternal directiveness significantly decreased during the intervention in three out of four participants. Since the intervention had a moderate effect on maternal directiveness, effect size was calculated. The Improvement Rate Difference (IRD) for each participant was: MP01=0.60 (60%); MP02=1 (100%); MP03=1 (100%); and MP04=-0.4 (40% in the negative direction). This indicates that the magnitude of the effect was large for two mothers, moderate for one mother and no effect in one mother. The average of the effect sizes indicated that the whole study had an effect size of 0.55 or 55%, which is a moderate effect.

The results regarding carry over effects are mixed. Between the two mothers who had high levels in directiveness during the baseline (MP02 and MP03), only MP03 had carry over effects while MP02 went back to the level at the baseline.

3.2.6. Maternal responsiveness

Table 3.5 shows the mean values for each participant at each phase. Average scores for the maternal responsiveness subscale were plotted for each participant for each phase (Figures 3.11 to 3.14). Maternal responsiveness improved during the intervention in those mothers who had low scores at the baseline (MP02 and MP03). For mother who had high values (MP01, MP04) during the baseline, maternal responsiveness levels at intervention were similar to those at the baseline. This may be due to a ceiling effect. During all follow-up sessions, these mothers' maternal responsiveness reached and maintained the highest score (five). Only MP03's data at follow-up were greater than those at the baseline.

Table 3.5 Participants' maternal responsiveness means and standard deviations (SD) at baseline, intervention and follow-up phases

Participant/Phase	Mean baseline (SD)	Mean intervention (SD)	Mean follow-up (SD)
MP01	4.50 (0.40)	4.87 (0.27)	5.00 (0.00)
MP02	2.00 (0.41)	3.27 (0.38)	2.00 (0.77)
MP03	1.06 (0.14)	2.50 (0.63)	2.11 (0.51)
MP04	4.78 (0.34)	4.77 (0.42)	5.00 (0.00)

Regarding latency, graphs revealed that once the intervention began, the maternal responsiveness immediately improved for participants MP02 and MP03.

Statistical comparisons using the 2SD and X-moving range chart methods revealed that mother's responsiveness significantly increased in MP02 and MP03 during the intervention; however, it did not statistically increase significantly in MP01 and, although non-significant, it decreased in MP04. When comparing the baseline with the follow-up phase using the same methods, retention of improvement in level of maternal responsiveness was observed only for MP03. Figures 3.11 to 3.14 display the 3-standard deviation band calculated using the X-moving range chart method for all of the participants. It can be also seen in these graphs that all the baselines were stable when intervention was implemented.

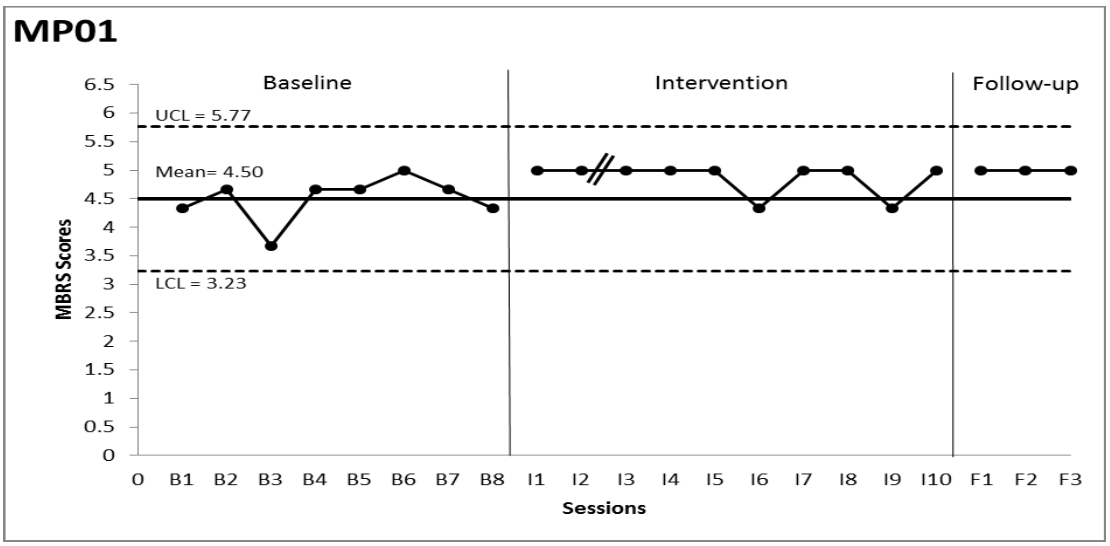


Figure 3.11 Comparison of subscale Responsive scores at baseline, intervention and follow-up phases for MP01 using X-moving range chart.
UCL: Upper Control Limits (+3-SD). LCL: Lower Control Limits (-3-SD).
// = two sessions missed

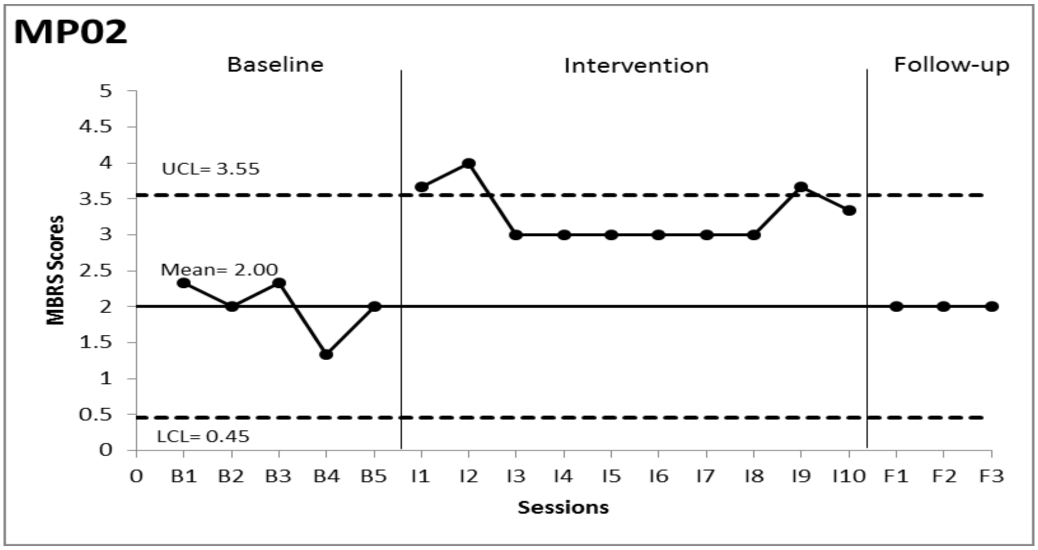


Figure 3.12 Comparison of subscale Responsive scores at baseline, intervention and follow-up phases for MP02 using X-moving range chart.
UCL: Upper Control Limits (+3-SD). LCL: Lower Control Limits (-3-SD).

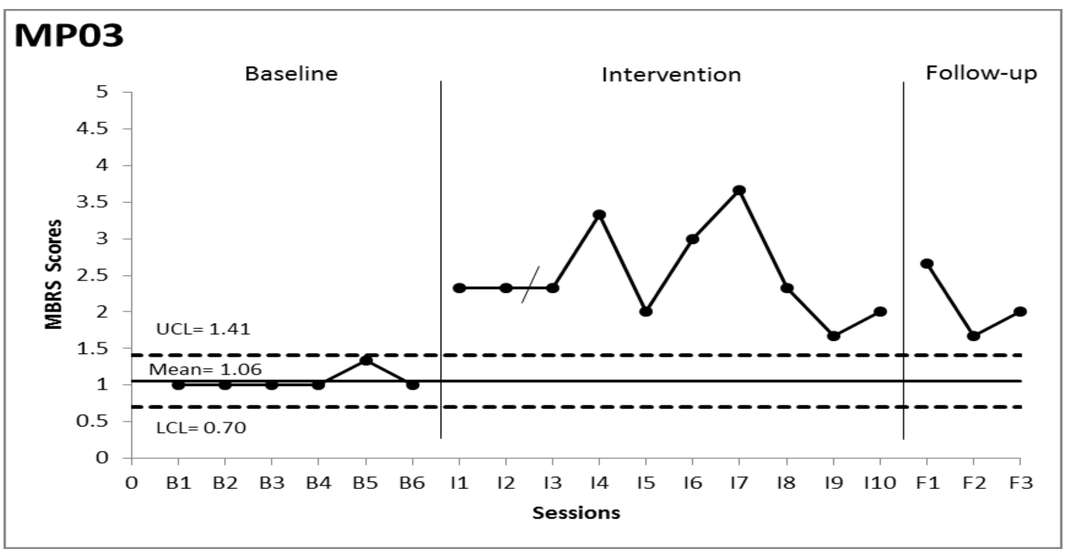


Figure 3.13 Comparison of subscale Responsive scores at baseline, intervention and follow-up phases for MP03 using X-moving range chart.
UCL: Upper Control Limits (+3-SD). LCL: Lower Control Limits (-3-SD).
/ = one session missed

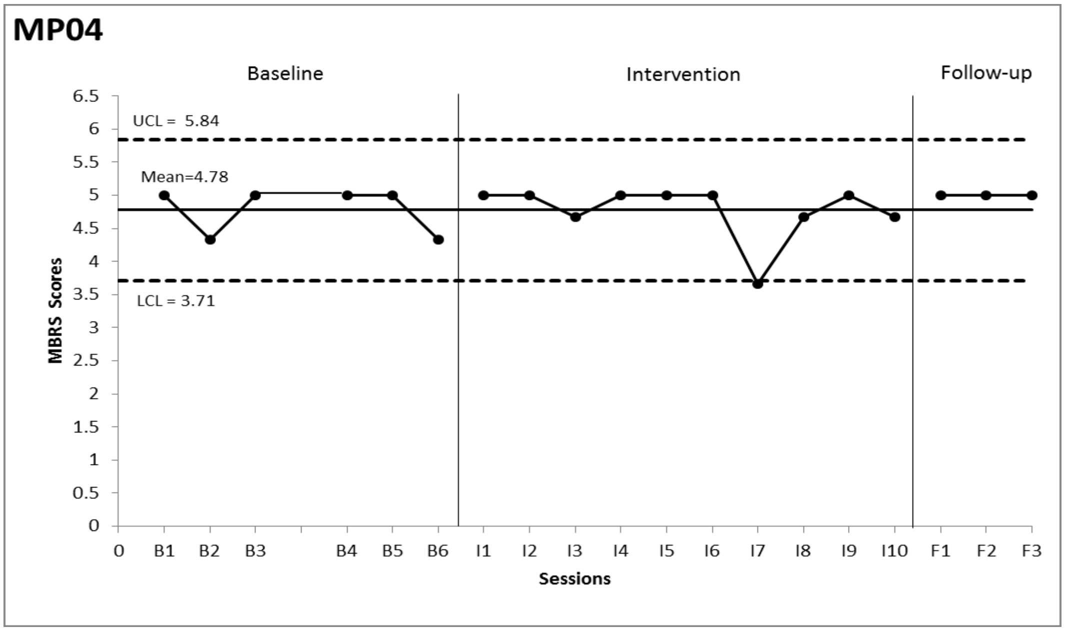


Figure 3.14 Comparison of subscale Responsive scores at baseline, intervention and follow-up phases for MP04 using X-moving range chart.
UCL: Upper Control Limits (+3-SD). LCL: Lower Control Limits (-3-SD).

Visual analysis of trends revealed that there were no evident trends during the baselines for MP03 and MP04. There was a slight accelerating trend in MP01's baseline and a decelerating trend in P02's baseline. There was no trend during the intervention for MP01, MP02 and MP03, and a decelerating trend for MP04. The slopes of the baselines (BL) and interventions (I) estimated from the celeration lines were: BL=0.07, I= 0.0 for MP01; BL= -0.34, I= 0.00 for MP02; BL=0.00, I= 0.00 for MP03; and BL=0.00, I= -0.13 for MP04. The C statistic calculated for MP01 revealed that there was no significant trend at the baseline (C= -0.1, SE=0.31, z=-0.32, p value = 0.75) nor when combining the scores for the baseline and the intervention (C=0.04, SE=0.22, z=0.16, p value=0.87). This indicates that there was no significant improvement in the trend of MP01's responsiveness once the intervention was implemented compared with the baseline. There was no trend during the follow-up for MP01, MP02, and MP04 while MP03 showed a non-linear trend during the follow-up; that is, her second score was lower than both the first and the third.

The visual analysis also revealed that the proportion of responsive sub-scale scores at baseline that overlapped with those at intervention were 100% for MP01and MP04; and, 0% for MP02 and MP03. This indicated that the level of responsiveness at the intervention were much greater than those at the baseline only in the mothers who had low scores during the baseline.

3.2.7. Maternal Affect/Animation

Changes in maternal affect/animation were not hypothesized in this study. A research question was included to explore whether there was a change in the mothers' affect/animation during the intervention and the follow-up compared with the affect/animation shown by the mothers in the baseline. Table 3.6 shows the mean values for each participant at each phase. Maternal affect/animation subscale average scores were plotted for each participant for each phase (Figure 3.15-3.18). Maternal affect/animation increased during the intervention compared with the baseline in MP01, MP02 and MP03 while MP04's affect/ animation decreased during the intervention. In all cases the change was small. Comparisons between the intervention and follow-up phases showed that MP01 and MP04's affect/animation increased during the follow-up. On the other hand, MP02's and MP03's means at the follow-up were smaller than those at the intervention. Comparisons between the follow-up and the baseline revealed that the mean at the follow-up were greater than those at the baseline for MP01, MP03 and MP04. MP02's mean at the follow-up was a bit smaller than that at the baseline. All of the changes between phases in maternal affect/animation were small.

Table 3.6 Participants' maternal affect/animation means and standard deviation (SD) at baseline, intervention and follow-up phases

Participant/Phase	Mean baseline (SD)	Mean intervention (SD)	Mean follow-up (SD)
MP01	4.03 (0.43)	4.28 (0.52)	4.87 (0.23)
MP02	2.28 (0.46)	2.94 (0.31)	2.27 (0.12)
MP03	2.77 (0.53)	2.90 (0.60)	2.87 (0.30)
MP04	3.40 (0.83)	3.26 (0.50)	3.73 (0.12)

Regarding latency, graphs revealed that once the intervention began, the maternal affect/animation maintained the same pattern showed during the baseline; in other words, the variable did not demonstrate any change as soon as the intervention started. In the same way, the affect/ animation was not affected once the intervention finished during the follow-up measures.

Statistical comparisons using the 2SD and X-moving range chart methods revealed that mother's affect/animation did not statistically change in any of the mothers during the intervention nor during the follow-up phases. Figures 3.15 to 3.18 display the 3-standard deviation band calculated using the X-moving range chart method for all of the participants. It can be also seen in these graphs that all the baselines were stable when intervention was implemented, although there was large variability.

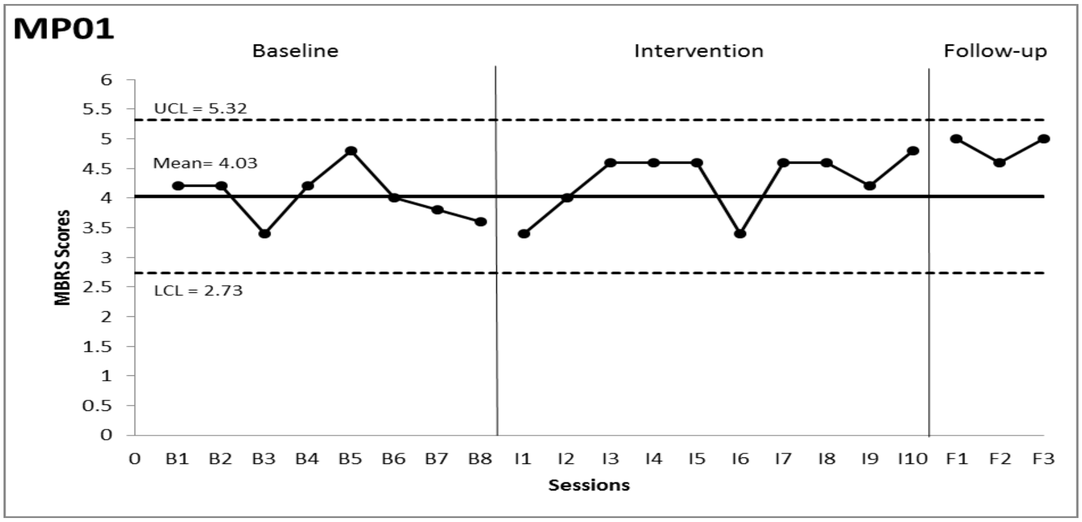


Figure 3.15 Comparison of subscale Affect/Animation scores at baseline, intervention and follow-up phases for MP01 using X-moving range chart.
UCL: Upper Control Limits (+3-SD). LCL: Lower Control Limits (-3-SD).
// = two sessions missed

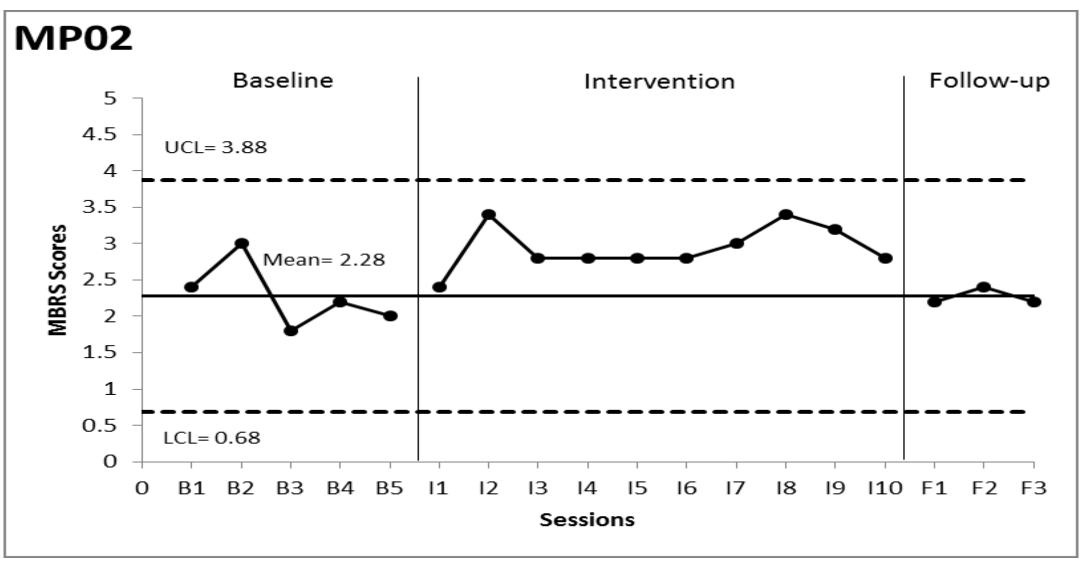


Figure 3.16 Comparison of subscale Affect/Animation scores at baseline, intervention and follow-up phases for MP02 using X-moving range chart.
The UCL: Upper Control Limits (+3-SD) and LCL. Lower Control Limits (-3-SD).

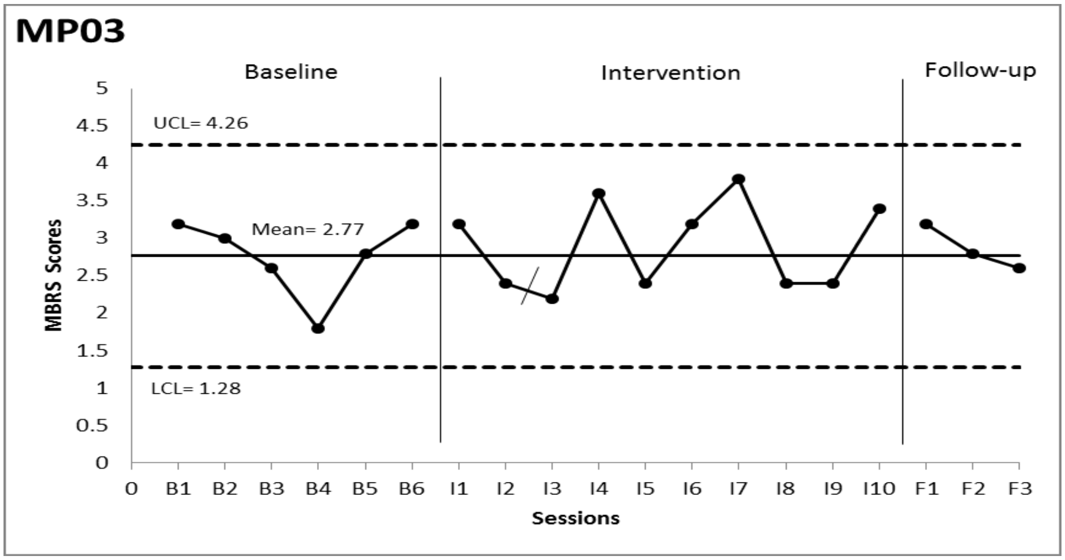


Figure 3.17 Comparison of subscale Affect/Animation scores at baseline, intervention and follow-up phases for MP03 using X-moving range chart.
The UCL: Upper Control Limits (+3-SD) and LCL. Lower Control Limits (-3-SD).
/ = one session missed

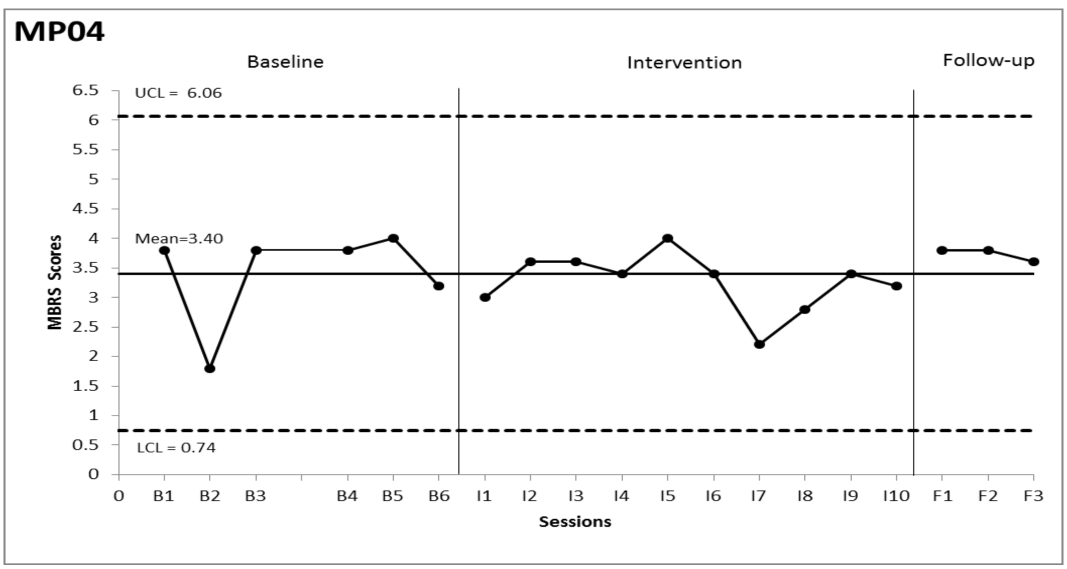


Figure 3.18 Comparison of subscale Affect/Animation scores at baseline, intervention and follow-up phases for MP04 using X-moving range chart.
UCL: Upper Control Limits (+3-SD). LCL: Lower Control Limits (-3-SD).

Visual analysis of trends revealed that MP01, MP02, MP03's affect/animation had a decelerating trend during the baseline while MP04's scores showed no trend during the baseline. During the intervention, MP01's scores showed no trend; MP02 and MP03's scores demonstrated an accelerating trend while MP04's scores had a decelerating trend. During the follow-up, MP01 and MP02's scores demonstrated no trend while MP03 and MP04's scores demonstrated a decelerating trend. The slope of the baselines (BL) and interventions (I) estimated from the celeration line were: BL= -0.14, I= 0.0 for MP01; BL= -0.4, I= 0.1 for MP02; BL= -0.13, I= 0.27 for MP03; and BL=0.00, I= -0.10 for MP04. The C statistic calculated for MP01 revealed that there was no significant trend in the baseline (C= 0.10, SE=0.31, z= 0.33, p value=0.74) nor for the combination of the baseline and the intervention scores (C=0.19, SE=0.22, z=0.85, p value=0.40). This indicates that there was no significant change in the trend of MP01's affect/animation once the intervention was implemented compared with the baseline.

The visual analysis also revealed that the proportion of affect/animation sub-scale scores at the baseline that overlapped with those at the intervention were 100% with both the highest and the lowest scores at baseline for MP01 and MP04. For MP02 and MP03, 70% of the data points at intervention overlapped with the highest data point at baseline, and 100% of the intervention scores overlapped with the lowest baseline score. This indicates that the pattern shown at baseline did not change during the intervention.

3.2.8. Clinical significance and social validation of the change

According to the 2SD band method, the level of playfulness of all the children demonstrated clinically significant improvement during the intervention, and mixed results during the follow-up phase. An analysis by participant using the criterion of "normative comparison" indicated that P01's ToP scores during the intervention ranged from 0.37 to 2.91. On the contrary, during the baseline P01's ToP scores mean was negative (-0.17) where six out of eight scores were located in the negative direction from zero (values ranging from -0.58 to 0.48). This indicated that P01 was not expressing playfulness during most of the baseline sessions. During the follow-up, the ToP scores ranged from 1.62 to 2.91. All of these scores were in the positive direction from zero, which indicated that P01 was more playful during this phase than during the intervention. This means that P01 demonstrated clear carry over effects in his level of playfulness.

P02's ToP scores during the intervention ranged from -0.64 to 0.49. Half of the intervention scores were in the positive direction from zero (sessions I5, I6, I8, I9 and I10) indicating that P02 was expressing playfulness during half of the sessions but the ToP scores mean was negative (-0.05). However, during the baseline P02's ToP scores mean was more negative (-1.56) and all of the scores were located in the negative direction from zero (values ranging from -1.7 to -1.34) indicating that P02 was not expressing playfulness during all of the baseline sessions. During the follow-up, P02's ToP scores ranged from -1.09 to -0.53. All of these scores were in the negative direction from zero which indicated that P02 was not playful during this phase. P02 did not have carry over the effect in her level of playfulness after the intervention finished.

P03's ToP scores during the intervention ranged from 0.29 to 2.37. All of the intervention scores were in the positive direction from zero indicating that P03 was expressing playfulness during the whole intervention. On the contrary, during the baseline P03's ToP scores mean was negative (-1.26) where all of the scores were located in the negative direction from zero (values ranging from -1.14 to -1.34) indicating that P03 was not expressing playfulness during all of the baseline sessions. During the follow-up, P03's ToP scores ranged from -0.34 to 0.22. Two out of three scores were in the negative direction from zero which indicated that P03 was not playful during the last two follow-up sessions. However, P03 demonstrated some carry over effect in his level of playfulness after the intervention finished.

P04's ToP scores during the intervention ranged from 1.26 to 2.51 (mean=1.82). All of the intervention scores were in the positive direction from zero indicating that P04 was expressing playfulness during the whole intervention. During the baseline, P04's ToP scores mean was positive (0.39) where all of the scores were located in the positive direction from zero (values ranging from 0.1 to 0.86) indicating that P04 was expressing playfulness during all of the baseline sessions. However, his scores were very close to zero; thus, the scores at the intervention demonstrated clinically significant improvement. During the follow-up, P04's ToP scores ranged from 0.63 to 1.03. All of the scores were in the positive direction from zero which indicated that P04 was playful during the follow-up sessions. However, P04 did not demonstrate a carry over effect in his level of playfulness after the intervention finished.

The 2SD band method demonstrated clinical significance in maternal responsiveness which improved during the intervention in those mothers who had low responsiveness scores during the baseline (MP02 and MP03). Maternal responsiveness only demonstrated clinical significance after the intervention for MP03. This method also demonstrated clinical significance in maternal directiveness which decreased for MP01, MP02 and MP03 during the intervention.

During the follow-up, there was a clinically significant reduction of maternal directiveness in MP01 and MP03.

Maternal affect animation did not show clinically significant change during the intervention nor during the follow-up for any of the mothers.

3.2.9. Social validation of the change

Social validation of the change is reported through the COPM and mother's satisfaction with the intervention interview. The results are presented by each mother-child dyad.

3.2.9.1. COPM

MP01 and P01: During the first administration of the COPM, MP01 identified three concerns in P01's play performance:

1) Attention: he was easily distracted during play activities and also during all of the activities he performed (Importance for MP01=10).
2) Coordination/Manipulation: he had difficulties in manipulating objects, toys and play materials (Importance for MP01=8).
3) Frustration tolerance: P01 gets upset if something does not go as he wants; this means low frustration tolerance (Importance for MP01=8).

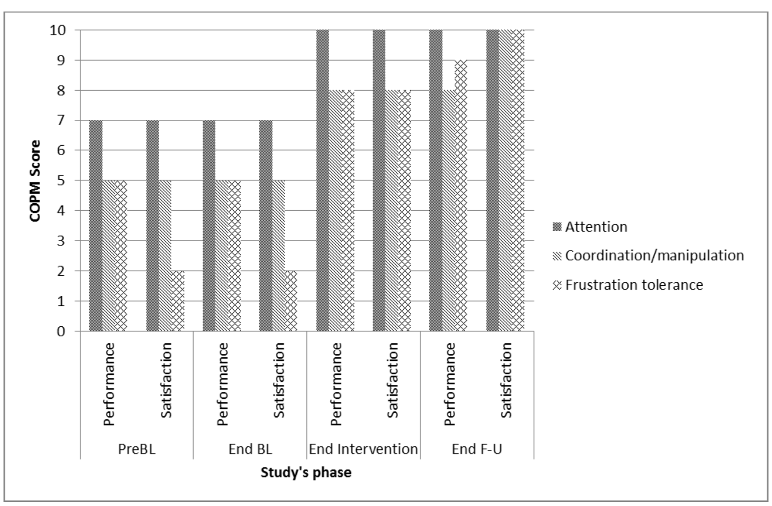


Figure 3.19 P01's COPM scores at initial assessment (PreBL), end of the baseline (BL), end of the intervention and end of the follow-up (F-U) phases as reported by MP01.

Figure 3.19 displays the scores assigned by MP01 during the four times in which the COPM was applied. MP01 assigned the same scores before and after the baseline was conducted. Thus, after the mother-child dyad played for one month during the baseline, MP01's perception about P01's play did not change. MP01 reported an improvement in P01's performance and her satisfaction regarding all of the concerns at the end of the intervention and at the end of the follow-up phases. The COPM scores for performance increased between three and eight units in all of the concerns reported by MP01, compared with the scores at the end of the baseline. All of the concerns reached the maximum COPM score for satisfaction at the end of the follow-up. MP01 reported that P01 improved during the intervention in all of the concerns not only in the activity with the robot, but also during the performance of daily activities, during therapy sessions, doing homework or during community activities (e.g., grab the railing when going on a bus). In addition, at the end of the follow-up phase MP01 reported that P01 showed improving motivation and engagement during activities and also his participation during interaction with people.

MP02 and P02: During the first administration of the COPM, MP02 identified three concerns in P02's play performance:

1) Coordination/manipulates: P02 had difficulties manipulating objects and toys (Importance for MP02=10).
2) Head posture: P02's head position was down during play and other activities (Importance for MP02=9).
3) Attention: P02 did not look at the objects she was interacting with (Importance for MP02=8).

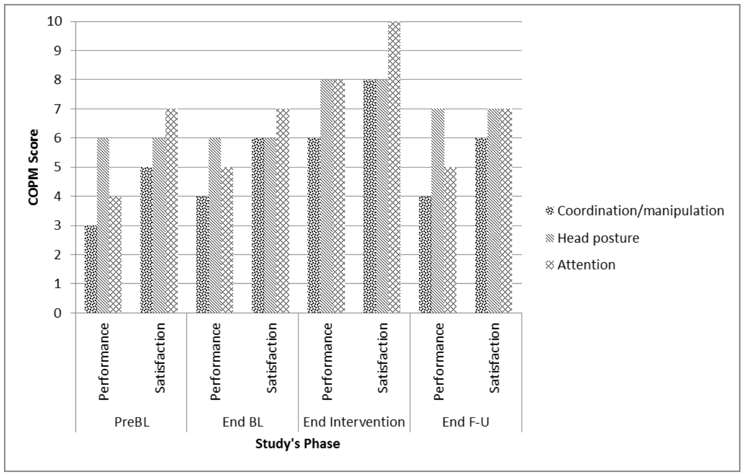


Figure 3.20 P02’s COPM scores at initial assessment (PreBL), end of the baseline (BL), end of the intervention and end of the follow-up (F-U) phases as reported by MP02.

Figure 3.20 displays the scores assigned by MP02 during the four times in which the COPM was applied. MP02 assigned the same scores before and after the baseline was conducted for the concern “head posture”. However, MP02 assigned higher scores in “attention” and “coordination/manipulation” at the end of the baseline. MP02 reported the reason for the difference was that they (MP02 and P02) never played using P02’s toys before the study was conducted. At the end of the intervention, MP02 reported an improvement between 2 and 3 units in P02’s performance and her satisfaction regarding all of the concerns. MP02 thought that P02’s ability to hit the switches constituted an improvement in her ability to manipulate objects. MP02 felt satisfied because P02 included her left hand in the activity despite difficulty using her hand. MP02 also perceived that P02 was very motivated and concentrating during the activity with the robot, and she positioned her head much better in order to look at the robot and the toys. MP02 perceived that P02 improved in gazing because the robot was very interesting for her. MP02 noticed that P02 made a sequence of steps: First, she looked at the toy she wanted; second, she thought about the order of the use of switches; third, she combined the use of two switches (the blue and the yellow) for making the robot get where the target toy was located. MP02 perceived that P02’s performance was very similar during the follow-up compared to the baseline.

MP03 and P03: During the first administration of the COPM, MP03 identified two concerns in P03's play performance:

1) Coordination/manipulation: P03 had difficulties manipulating objects and toys (Importance for MP03=10).

2) Persists with the play activity: He did not try too hard to manipulate objects (Importance for MP03=10).

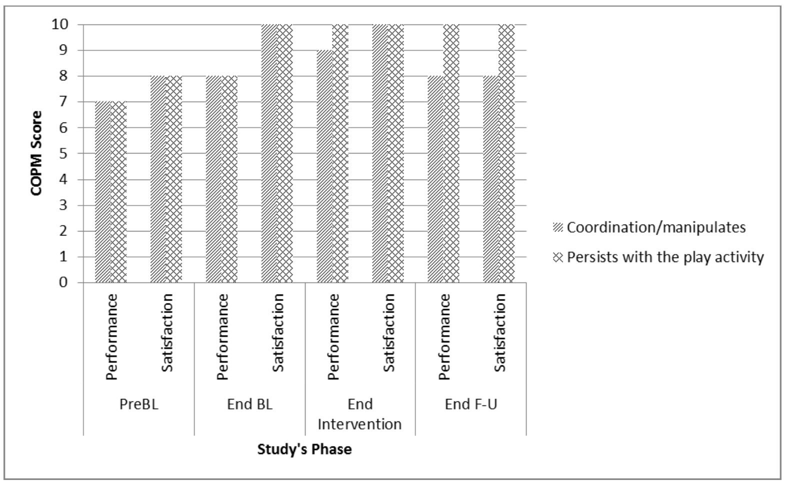


Figure 3.21 P03's COPM scores at initial assessment (PreBL), end of the baseline (BL), end of the intervention and end of the follow-up (F-U) phases as reported by MP03.

Figure 3.21 displays the scores assigned by MP03 during the four times in which the COPM was applied. MP03 assigned higher scores to the two concerns at the end of the baseline than in the pre-baseline assessment. MP03 reported that the reason for the difference was that before the study was conducted they (MP03 and P03) never played using P03's toys. At the end of the intervention, MP03 reported an improvement between 1 and 2 units in P03's performance and her satisfaction regarding all of the concerns. MP03 observed that P03 improved in grasping and pinching objects with his left hand because of the intervention. MP03 perceived that P03 was doing the fine motor activities better than before the intervention started. MP03 also reported that P03's occupational therapist and special educator at the rehabilitation centre told her that P03 was performing better in fine motor activities. At the end of the follow-up MP03 identified improvement only in "persists with the play activity"; she perceived that P03 was more interested in interacting with objects and tried harder to manipulate them.

MP04 and P04: During the first administration of the COPM, MP04 identified three concerns in P04's play performance:

1) Posture: Unsafe. He thinks he was going to fall down (Importance for MP04=10).

2) Coordination/manipulation - Reaching objects: He was not able to reach the objects he wanted by himself (Importance for MP04=10).

3) Communication: It was difficult for him to communicate what he wanted (Importance for MP04=10).

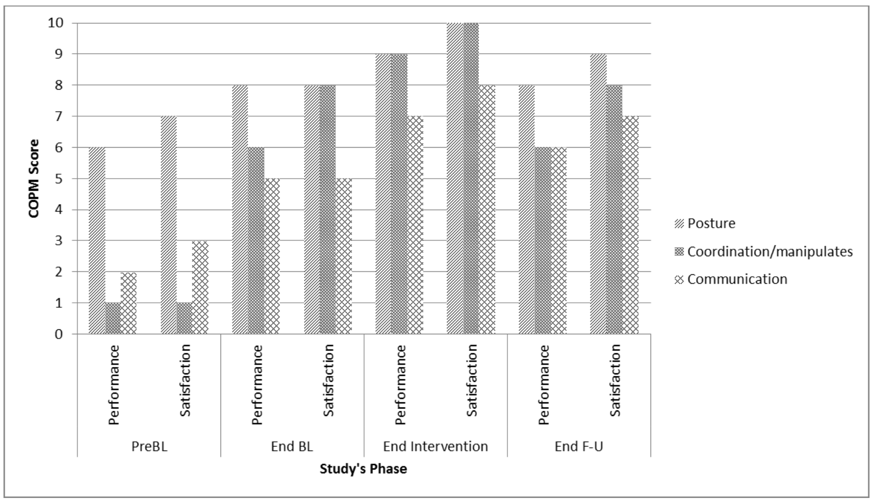


Figure 3.22 P04's COPM scores at initial assessment (PreBL), end of the baseline (BL), end of the intervention and end of the follow-up (F-U) phases as reported by MP04.

Figure 3.22 displays the scores assigned by MP04 during the four times in which the COPM was applied. MP04 assigned higher scores for all concerns at the end of the baseline than in the pre-baseline assessment. She reported the reason for the difference was that they (MP04 and P04) never played using P04's toys before the study was conducted. At the end of the intervention, MP04 reported an improvement between 1 and 3 units in P04's performance and her satisfaction regarding all of the concerns. MP04 observed that P04 was more stable when playing sitting in a chair during the intervention than during the baseline. MP04 reported that she was satisfied with P04's performance because she had noticed that P04 realized that he was able to do more things independently; for example, to reach toys using the robot. MP04 perceived that P04's communication improved with the robot because she felt that it was easier for her to know what he wanted to play.

3.2.9.2. Mother’s satisfaction with the intervention

All of the mothers expressed their satisfaction with the intervention and that their children enjoyed playing with the robot. Mothers reported that the robot was something new, novel, different and innovative. A summary of the interview with each mother is presented below.

MP01 felt that the robot allowed P01 to feel that he was in control and he did what he wanted to do during play. MP01 thought that playing with the robot was different than playing without the robot. During his play without the robot P01 had to try to move the cars with his hands very close to him, while with the robot he felt that he was able to move things far away, which was new for him. MP01 believed that the robot was a tool that let P01 interact with his toys and it made the play "more real" because the robot allowed him to interact and manipulate the toys in different ways and it was much easier compared to when he played without the robot. At home, P01 was talking about the robot all the time to his father, the little brother, aunt and cousins. In kindergarten, he was talking about the robot constantly with his teacher who was very interested in seeing what P01 did with the robot. The members of the family commented that P01 seemed happier and more motivated to develop activities ever since he has been in contact with the robot. The robot had motivated him to assist in their rehabilitation program. MP01 reported that one of her cousins had seen positive changes in P01’s posture, his state of alertness and attention. Some of the MP01’s neighbors commented that P01 talked more during social interactions with them. Teachers have said that P01 invents new games and that he makes creative use of toys. P01 recently joined this kindergarten, so his teachers were discovering his skills. MP01 believed that what teachers reported was due to the intervention with the robot.

MP02 reported that P02’s play with the robot was different because with the robot, P02 was the owner of the play and played by herself and manipulated the toys that she wanted, while without the robot, the play was controlled more by the mother and P02 was limited to paying attention to what the mother did. MP02 also perceived as positive that P02 felt that she could play alone with the robot and she did not need the support of her mother. MP02 observed that the robot was a tool for P02 to interact with toys by moving or pushing them. The mother suggested that the robot could be larger and could have grips for grabbing the toys. The mother thought that if there was a button to make the robot grab objects with grips, it would be more fun for P02. P02's father showed interest in knowing if P02 was impressed with the robot. P02's physical therapist commented that P02 had improved attention and hand-eye coordination when playing with the robot. The mother said that it was hard for her to pay attention to an activity and to finish it, but with the robot, P02 paid attention and developed the activity throughout the session. For P02 the experience was very positive because the robot was something new for her and the situation of playing with her toys was also new, since P02's poor motor control didn't allow her to play with objects.

MP03 observed that P03 very quickly learned to control the switches to move the robot in all directions. When they played without the robot she manipulated the toys, but she did not know if the games were what P03 wanted to play. When P03 played with the robot, he was controlling the play. P03 was the one who played and he did not depend on his mother to play; for example, MP03 did not have to manipulate toys for him. The mother noted the fact that P03 played with what he wanted was a positive sign of independence. The mother expressed that the robot was a tool that helped P03 manipulate his toys. The mother perceived that P03 made the robot choose the toys he wanted and then he did what he wanted to do with them; for example, to push them or hand them over; in other words, he decided what he wanted to play with. MP03 noticed that after the intervention with the robot, P03 asked her to take his toys to his room because he wanted to play. The mother felt that this indicated that P03's interest in playing with his toys had increased because P03 had never requested toys until he had the experience with the robot. The mother also believed that members of the family liked to see that P03 was able to control the robot himself. MP03 also reported that P03's fine motor skills improved during the intervention; for example, he interacted more with his toys and was beginning to pinch with his left hand. The mother said that the therapists at the rehabilitation centre noticed that P03 had improved his left hand fine motor skills and could reach midline with his arms. He also increased his concentration. The mother reported that this was due to the intervention with the robot.MP04 perceived that the robotic intervention was very timely because it helped P04 gain the skills necessary to control his power wheelchair (the health care system provided a power wheelchair for the very first time to him in the fifth intervention session). MP04 also felt that when P04 played with the robot, he showed more interest in the play than when he played without the robot. She noticed that the robot was a tool which allowed P04 to interact with his toys by reaching the toys that he wanted and to do what he wanted with them. The mother suggested to improve the robot's scoop since it fell down very easily and made P04 ask for help to put the scoop back, because he couldn't do it by himself. The mother reported that no one else had commented or noticed a change in P04 during the intervention.

4. Discussion

This study investigated the effect of a robot-based intervention for promoting free play on: 1) the child's playfulness; 2) mother's directiveness, responsiveness, and affect/animation; and 3) mother's perceptions of the child's play performance and satisfaction with their performance. This study also identified the mother's satisfaction with the robotic intervention. The study's protocol was tested in a pilot study with a child with cerebral palsy and her mother followed by a partially non-concurrent multiple baseline design with four children with cerebral palsy and their mothers. The intervention was the availability of a Lego robot during free play at home. The main findings of this study are that the robotic-based intervention showed strong evidence of increasing playfulness in children with severe motor impairment due to cerebral palsy; moderate evidence of decreasing mother's directiveness; and no evidence of an increase in responsiveness or change in the affect/animation in the mothers of those children during the intervention. This chapter discusses the findings regarding each of the study's research hypotheses and questions followed by a discussion about the study's strengths, limitations and future research.

4.1. Children's playfulness

It was hypothesized that the ToP scores of children with cerebral palsy would increase during the intervention compared with the ToP scores in the baseline. Results revealed that playfulness significantly increased both visually and statistically during the intervention in all four participants. The criterion for demonstrating evidence in single case research is "at least three demonstrations of the intervention effect along with no non-effects" (Kratochwill, et al., 2010). Thus, the results provide strong evidence (causal relation) to support Hypothesis 1A of this study. Research question 1B asked whether children's playfulness changed following the intervention in comparison with the baseline. The results revealed that the level of playfulness following intervention significantly increased both visually and statistically in three out of four children compared with the baseline.

The ToP scores at the baseline provide information about the level of playfulness in children with cerebral palsy. P02 and P03 had negative scores during the whole baseline and P01 had negative scores during 75% of the sessions indicating that during the baseline, they were generally not expressing playfulness. This finding is consistent with previous research in which most infants and children with cerebral palsy achieve low scores in playfulness (Harkness & Bundy, 2001; Okimoto et al., 1999; Rigby & Gaik, 2007). Only P04 had positive values during the baseline indicating that he expressed playfulness during the baseline. The sample had little variability in regard to motor impairments (all children had limited self-mobility) and more variability in cognitive levels. Children with lower cognitive levels had the lowest ToP scores, and those with higher cognitive levels had higher ToP scores. These results are consistent with the findings of Chang et al. (2014) that cognitive-behavioral problems and gross motor function explain 41% of the variance in playfulness expressed by children with cerebral palsy with levels III-V on the GMFCS. They also found that cognitive-behavioral problems had a stronger correlation with playfulness than did motor function. In the present study, the cognitive impairment and the motor function were related to the ToP scores achieved during the baseline than gross motor function. This suggests that children with severe motor impairment with no severe cognitive limitation can be playful but the motor limitation prohibits them from expressing playfulness and engaging in free play. Due to the small sample size in this study these findings should be explored in future research.

The robot resulted in the playfulness of all of the children increasing during the intervention. P01, P03 and P04 demonstrated playfulness as their ToP scores were in the positive direction from zero. P02's ToP scores were negative, indicating that she did not express playfulness during the intervention, even though her scores statistically and clinically increased significantly in this phase. Her level of playfulness had a clearly increasing trend during the intervention. All children demonstrated an increasing trend in their level of playfulness during the intervention.

Mothers observed that it was easier for children to control the robot as the intervention advanced. Operating a Lego robot using three switches can be cognitively demanding for typically developing children younger than five years old (Cook et al., 2012; Poletz et al., 2010). Children with motor impairments gain skills for operating a robot as they practice (Cook, et al., 2002; Cook, et al., 2011). In this study the robot allowed children to learn through free play. As they developed more skills to operate the robot, they became more playful. This finding supports

Sutton-Smith's (2001) assertion that free play is a powerful means of learning by innovative problem solving strategies where children learn while using their skills and enjoying the play.

The ToP developer typically has discussed research results in terms of the ToP elements of Intrinsic Motivation, Control (self and shared), Frame, and Freedom to suspend reality and their corresponding items (Bundy, Shia, Qi, & Miller, 2007; Harkness & Bundy, 2001; Leipold & Bundy, 2000). A similar approach is used here. Regarding the element of play Intrinsic Motivation, children had relatively low scores in *Engages/intensity* and *skill* during the baseline. P02 and P03 especially were distracted during the baseline sessions and in some sessions it was questioned whether they were playing. The positive impact of the robot on the element Intrinsic Motivation was reflected in the items *Engages*, *Persists* and *Interacts with objects* that increased in all of the children during both the intervention and follow-up. During the intervention, the engagement increased because the robot was very motivating for all children as reported by their mothers. Children commented about the robot to relatives, teachers and neighbors. The researcher also noticed that all children were very excited when she arrived at their homes or the rehabilitation center with the robot and they focussed on the robot rather than the researcher. For example, P03 said "the robot arrived!"; P02 said "robot" ; P04 asked the researcher to play longer than 15 minutes during the intervention sessions, and P01 asked his mother every night "Is tomorrow a robot day?" After some sessions, P01, P02, and P04 wanted to show to their relatives what they did with the robot. Additionally, all children were sick at some point of the study, and when asked if they felt good enough to play with the robot all of them wanted to have the robotic session.

Children in this study achieved relatively high scores in the item *Persists* during the baseline and the score on this item increased during the intervention in all children. Children were persistent about what they wanted to do with the robot and the toys. For example, P02 tried to release the robot using two switches when it got stuck. MP02 offered help but P02 said "no" and continued trying by herself. When the robot scoop fell off the robot P04 tried very intensely to catch it using the robot instead of asking his mother to catch it. MP01, MP03 and MP04 also perceived an increase in their children's persistence in performing activities during and after the intervention. These results regarding persistence in an activity during all the study's phases are consistent with Harkness and Bundy (2001).

The item *Interacts with objects* was low in all children due to their fine motor limitations, and they showed low interest in toys. It was common during the baseline for children with MACS level V (P02 and P03) to have mothers manipulating all of the toys and children simply observing what their mothers were doing. This was also observed in Gowen, et al.'s (1992) study. Interaction with objects improved during the intervention as all children used the robot for interacting with their toys. The interaction with objects was more intense because children wanted to see what happened when they tried to knock, push, carry or tread on toys. When children had the robot available, they were able to plan and execute interaction between the robot and the toys. For example, P03 asked his mother to load a car cushion toy on the top of the robot, the toy was about five times bigger than the robot, and initially his mother refused to do it but he insisted. When MP03 placed the toy on the robot, the robot could carry it for a short distance. Thus, children showed that they were able to explore an object's properties while playing with the robot. Reilly (1974) describes this kind of behaviour as curiosity that leads to exploration through which children test reality.

During the baseline, all mothers except MP03 (who chose the toys to play with) tended to ask the children about what they wanted to play with at the beginning of the sessions. However, once children chose toys, all the mothers tended to decide how to play with those toys and to initiate play themes. Children tended to not modify activities and they were repetitive during the baseline sessions. During the intervention all children demonstrated an increase in the element of play Control-self, specifically the items *Decides*, *Modifies*, *Initiates* and *Transitions*. During the intervention all children made the robot go to the toy with which they wished to interact, and mothers tended to ask children how they wanted to play and then comment on the child's selections. When they had the robot, all children initiated more play activities, especially P02 and P03 who initiated almost no activities during the baseline. All children except P02 made modifications to the activity in order to explore different objects using the robot. For example, P03 made the robot move forward by sequentially hitting the switches to turn. P04 asked his mother to build a challenging slalom course with narrow spaces for the robot to go through, and P01 tried to make the robot climb therapeutic equipment (a mat and steps) in the room. During the follow-up, all children showed carry-over effects reflected in improvement in the items *Decides* and *Initiates*. This suggests that after the intervention children were more confident initiating and deciding about the activity they wanted to do compared with the baseline.

The elements of play Control-shared and Frame are related to the interaction with the playmate. It was observed that P02 and P03 were extremely passive and compliant (reflected in the items *Social Play, Negotiates, Gives,* and *Responds*) during the baseline. They accepted all the activities that the mothers initiated without protest or attempts to modify their mothers' ideas. This result is consistent with previous research that reported that children with cerebral palsy are more passive, less responsive and more compliant when they play with their mothers than typically developing children (Barrera & Vella, 1987; Hanzlik, 1989; Lieberman, et al., 1995) and that mothers generally initiate the interaction (Pennington & McConachie, 2001). During the intervention, these items improved, especially in P02 and P03. When using the robot children were highly motivated in communicating what they wanted to do. In fact, all children improved in the items *Responds to other's cues* and *Gives cues*. P02, P03 and P04 spent more time during the sessions giving clear cues than during the baseline. This suggests that children were more communicative, as they wanted to communicate exactly what they required from their mother in order to do what they wanted with the robot and the toys. This is consistent with previous research that found that when children control a robot they used different strategies such as eye gaze for communicating their desires (Cook et al., 2000). For example, P03 and P04 got frustrated when mothers did not understand what they wanted to do; when their mothers finally responded in the way they needed, they seemed satisfied and were able to continue their play activity. All children were active during the interaction with their mother as they were motivated by the robot and had ideas about what to do. This suggests that when children are provided with a robot as a tool that supports their independence and participation during free play, they are more responsive, more active and less compliant; they provide ideas for the play activity and can lead the play. This change in the interaction was retained during the follow up for P01 and P03 suggesting that these children became more active in having their play interests met.

Two items are of interest in the element of Freedom to suspend reality, *Unconventional* and *Pretends*. The item *Unconventional* (use of objects or people in unconventional ways) was low in all children during the baseline, especially in P02 and P03 (zero in both children). When playing with the robot, P01, P03 and P04 improved in this item because they used the robot and the toys in innovative and creative ways. For example, P03 asked his mother to put a pile of plastic donuts on the top of the robot and then he tried to make the donuts fall down by moving the robot forward and backward repeatedly in order to destabilize the pile of toy donuts. P04 used the robot to coil a toy car spring and release the car. This suggests that children were more creative when they were able to interact with their toys through the robot. Children did not show carry over effects in the item *Unconventional*. Thus, it seems that the robot allowed children to interact with objects in creative ways, and that children with severe motor impairments have the ability to interact with objects in creative ways but they need alternative means (e.g., the robot as assistive technology) to express it.

All children had low scores in the item *Pretends* during the baseline. This is consistent with Pfeifer and colleagues (2011) who found that children with cerebral palsy with level IV and V at the GMFCS showed moderate or significant delay in pretend play. P01, who engaged in more pretend play, also had the highest PTI-2 score in verbal abstractions. Two children demonstrated improvement in pretend play. P01 demonstrated more pretend play in both the intervention and the follow-up. P03 had a higher pretend play ToP score during the follow-up phase compared with that at the baseline and at the intervention. For example, P01 used the robot as a bus and P03 took a puppet to an imaginary hospital using the robot. This was possibly because as P01 and P03 were more confident interacting with toys, their pretend play was easier to express. Another possible explanation for P03's improvement is that his mother was less directive during the follow-up giving him more time to express his pretend play. The robot may have more potential to promote functional play or games with rules than it does promotion of pretend play. Further research about the possibilities of the robot in pretend play is needed.

Most of the items that consistently improved in all children belonged to the elements of play Intrinsic Motivation and Control (self and shared). From a theoretical point of view, this suggests that during the intervention children were performing in a psychological state called the "flow channel" (Csikszentmihalyi, 2008) in which the person feels enjoyment because there is a balance or a good match between a person's skills and the challenges of the environment. The Flow theory describes flow as a psychological state in which the individual experiences pleasure and enjoyment while doing an activity. Csikszentmihalyi identifies the elements that make enjoyable activities so gratifying. These elements are: challenging activities that require skills, merging of awareness and attention, clear goals and feedback, and totally absorbing activities (emotional connection with the activity). Other elements are that the activity is autotelic, the individual feels in control of her actions and of the environment, feels loss of self-consciousness and a distortion of the time spent in the activity (more or less than in reality). The flow state can be a feeling during any activity including work (Csikszentmihalyi, 2008). Bundy (2010) has associated the flow channel with the Intrinsic Motivation and Control-self elements of playfulness. Munier et al. (2008) pointed out that the flow channel is present in children's object play. Thus, during the intervention children were more intrinsically motivated and controlled the activity. They experienced enjoyment because there was a better match (compared with the baseline) between their skills and the challenges imposed by the objects with which they wanted to interact. One could make the assertion that the robot functioned as an augmentative manipulation device that allowed children to perform in a "flow channel." This also suggests that children experienced a playful exploration that was described by Burghardt (2005) as "diversive exploration" of the environment, which is an exploratory behaviour, companied by positive feelings. Coplan et al. (2006, p. 75) suggested that children's free play is driven by the question "what can I do with this object or person?" In the present study, the question that drove the play was "what can I do with these objects using the robot?" The robot allowed children to explore, to experience control on the robot and the toys, to create play activities, to solve problems, to try, and to lead the play. In summary, use of the robot allowed them to experience how playing feels.

In terms of the HAAT model and its elements (Cook & Polgar, 2008), during the intervention children were provided with Assistive technology (the robot). Children' s ability to interact with objects increased so that their skills were more balanced with their Physical context's (toys) demands compared with those at the baseline. Thus, children were able to have an impact on their physical context. Children were intrinsically motivated, felt in control and were creative while using the robot for interacting with their toys. Thus, children were able to engage in the Activity (free play) and demonstrate more playfulness compared with the baseline. The Social context changed as mothers perceived improvements in children's play performance and felt satisfied with their children's performance. Some mothers demonstrated positive changes in their levels of responsiveness and directiveness which in turn made them better playmates. Consistent with this finding, the Let's Play Model recommends family-centered interventions using assistive technology to facilitate play and development in children with disabilities (Lane & Mistrett, 2002).

The observed carry over effects can be explained by a probable increase in children's mastery motivation or self-efficacy since Intrinsic Motivation and Control elements of play have been associated with a sense of mastery motivation (Jennings et al., 1988; Majnemer, Shevell, Law, Poulin, & Rosenbaum, 2010) and self-efficacy (Reid, 2002). Thus, following the intervention children showed an increase in items such as *Engages, Persists,* and *Interacts with objects* (intensity) that belong to the element Intrinsic Motivation; and *Decides, Initiates,* and *Negotiates* which belong to Control element of play.

Another possible explanation for carry over effects in playfulness is the decrease in MP01, MP02 and MP03's directiveness, and the increase in MP03's responsiveness at the follow-up. In addition to the improvement perceived by mothers in their children's performance in play, mothers became better playmates who enabled children to express playfulness. If caregivers of children with disabilities value and promote play, children will demonstrate fewer impairments (Harkness & Bundy, 2001). Parent-child interactions where parents respond contingently and appropriately to children's needs and interests generate opportunities for children to develop a sense of mastery (Crockenberg & Leerkes, 2000).

Another consideration for the changes is that MP02, MP03 and MP04 reported that they did not encourage their children to engage in play with objects before the study. Instead, they commonly performed social play in activities such as watching movies at home, cuddling the children, singing songs or reading stories. Since this study forced mothers to encourage their children to engage in object play, over time mothers acquired more experience and skill to perform this type of play with their children. The result was a change in some mothers' responsiveness and directiveness.

The last subject of discussion regarding playfulness is the fit statistics of the data. In this study, 87% of data was within the acceptable limits of the Rasch model. This is less than the desired 95% fit but similar to previous research where 88% of data was within acceptable limits in children with motor impairments (Harkness & Bundy, 2001); 88% of the data fit the model for children with attention deficit hyperactive disorder (Leipold & Bundy, 2000), and 70% fit of the model in children with sensory processing dysfunction (Bundy, et al., 2007). Data that did not fit the Rasch model indicates that some scores of some items in these sessions had unexpected values. This means, easy items had unexpected low scores or hard items had unexpected high scores (Bundy, et al., 2001).

For example, during the baseline P01 had unexpected high values in the items *Mischief or teasing* and *Clown or jokes*. P03 and P04 also had an unexpected high score in the item *Mischief or teasing*. This is consistent with Harkness and Bundy (2001) who had similar results and explained that the reason could be that children with physical impairments use humor as a means to gain attention. P01 and P03 had unexpected low scores in the item *Decides* during the baseline which was also found by Harkness and Bundy (2001) who asserted that making decisions about play is difficult for children with motor impairment. P04 had an unexpected low value in the item *Unconventional* during the first intervention session. This may be due to replicating an activity performed during the training (a slalom course). P04 also had unexpected low values in the item *Gives/skills* in two intervention sessions. This may be explained by his motor impairment that imposes limitation for his communication.

At all sessions of the follow-up, P01 had unexpected low scores in the item *Interacts with objects/skills,* and *Engaged/extent*. In one of the follow-up sessions, P01 asked his mother to get out of the sitter chair and sit on the floor without a supporting system, he fell down and was scared. That event may explain his unexpected low score in the item *Safe*.

4.2. Maternal directiveness and responsiveness

It was hypothesized that mothers of children with cerebral palsy would show significantly less directiveness when their children were able to use a robot as an augmentative manipulation device during free play compared with the baseline. The results revealed that maternal directiveness significantly decreased both visually and statistically during the intervention in three out of four participants. According to the criteria for demonstrating evidence in single case research, the results provide moderate evidence to support the hypothesis 2A of this study with three demonstrations of an effect and one demonstration of a non-effect (Kratochwill, et al., 2010). The research question 2B asked whether mothers' directiveness would change following the intervention in comparison with the baseline. The results revealed that the level of maternal directiveness significantly decreased both visually and statistically in two out of four mothers compared with the baseline.

It was hypothesized that mothers of children with cerebral palsy would show significantly more responsiveness when their children were able to use a robot as an augmentative manipulation device during free play compared with the baseline. The results showed that maternal responsiveness increased both visually and statistically during the intervention in two out of four participants. The significant improvement was found in those mothers who had low responsiveness scores during the baseline (MP02 and MP03). According to the criteria for demonstrating evidence in single case research, the results provided no evidence to support the hypothesis 3A of this study because there were not "at least three demonstrations of the intervention effect along with no non-effects" (Kratochwill, et al., 2010, p. 16). The intervention was not effective in mothers who had high levels of maternal responsiveness during the baseline; thus, the lack of improvement could be due to a ceiling effect. The research question 3B asked whether mothers' responsiveness changed following the intervention in comparison with the baseline. The results revealed that the level of maternal responsiveness significantly increased both visually and statistically in one out of four mothers compared with the baseline.

During the baseline two mothers showed high levels of maternal directiveness and low levels of maternal responsiveness toward their children (MP02 and MP03). This is consistent with previous research that found that mothers of children with a motor limitation tend to be more directive and less responsive than mothers of typically developing children during play (Blacher et al., 2013; Lieberman, Padan-Belkin, & Harel, 1995; Kim & Mahoney, 2004).

Regarding directiveness, during the baseline MP02 and MP03 were very quick in their interactions with their children, selecting all the play themes and almost all the toys. MP03 switched the play theme and toys about every minute during the sessions. These observed behaviors are consistent with Marfo's (1992) finding that mothers of children with disability tended to not wait for children to respond. Pennington and McConachie (1999) found that mothers of children with cerebral palsy generally dominated the interaction during play. This high level of directive behavior might be due to P02 and P03 having the most severe limitations in manual ability and cognitive level, combined with limited spoken language that affected their capability to initiate interactions. P02 and P03's scores in the ToP item *Initiates* revealed that this item was the lowest in the scale (zero) in almost all of the baseline sessions. In this regard Marfo (1992) found that mothers tended to be more directive when their children had low initiative levels for interaction with objects and people. Another possible explanation for the high directiveness might be that mothers felt uncertain about how their children wanted to play. MP03 expressed during the interview that she did not know whether or not the play themes she performed during the baseline were what her son wanted. MP02 described her manipulation of the toys while P02 just watched the play during the baseline was because of her daughter's severe limitations in manipulating toys. This corresponds to previous research reporting that caregivers and playmates of children with disabilities may have difficulty understanding the child's communication attempts (Bronson & Bundy, 2001). Another explanation might be that mothers have difficulty finding effective strategies to engage the child in joint activities during free play. Mothers can use directiveness as a simple strategy to redirect the child's attention (Blacher et al., 2013). Similarly, in the present study, mothers verbally or physically prompted children in order to engage them in the activity when children seemed disengaged. Mothers also tended to direct the play sessions for children to achieve developmental goals (therapeutic, educative) rather than being sensitive and responsive to children's interests and desires (Rigby & Gaik, 2007). For example, MP02 continually requested visual contact with the toy that MP02 was manipulating and for her daughter to position her head. MP03 constantly requested P03 to grasp toys, name the color and try to perform bimanual activities. Probably, children's therapists have an impact on mothers' styles of interactions during play as the mothers seemed to be modelling therapy session activities and approaches rather than encouraging children to play.

MP02 and MP03expressed minimal responsiveness to their children during the baseline. MP02 had little visual contact with P02 as she looked more frequently at the toys that she was manipulating than at P02 missing many of P02's cues. MP03 frequently ignored P03's vocalizations and verbalizations. Both mothers (MP02 and MP03) had the least playful children during the baseline. This is consistent with previous research related to children with disabilities where playfulness was moderately positively correlated to parent's responsiveness (Chiarello, et al., 2006). In the same way, high levels of maternal responsiveness in mothers of typically developing children are associated mostly with children's responsiveness (Smith, 2010). Thus, a possible explanation of the low levels of maternal responsiveness in MP02 and MP03 during the baseline can be explained by the low playfulness expressed by their children. Similarly, the high levels of responsiveness of MP01 and MP04 can be explained by the higher level of playfulness expressed by P01 and P04 compared with those of P02 and P03.

During the intervention, all mothers in the study seemed more willing to respond to children's play interests when the children were using the robot. However, the change was significant only in those mothers who showed low levels of responsiveness at baseline (MP02 and MP03). At the beginning of the sessions all mothers asked their children about what and how they wanted to play, and usually commented about what the children were doing with the robot. Since the robot used in this study required assistance from the mother for things such as loading toys on the top of the robot, mothers constantly looked at their children to monitor their behaviors, and were ready to respond when children needed assistance. In the same way, during the intervention MP01, MP02 and MP03 were slower in their interaction, gave more time for their children to react, and tended to allow children independence in the performance of their play. All mothers seemed interested in watching what their children wanted to do with the robot.

These findings suggest that as children became more playful, some mothers, in turn changed their directiveness and responsiveness. This shift in maternal behavior can be analyzed through the lens of attachment theory (Cassidy & Shaver, 2008). Attachment theory explains a positive mother-child interaction as a circle of secure attachment that requires clear cues from, clear understanding of and responsiveness to each other in the dyad (Marvin, et al., 2002). In this respect, Kim and Mahoney (2004, p. 36) asked the question "Are parents more responsive and affective because their children are more active and engaged, or do children become more active and engaged because their parents have a responsive and affective style of interaction?" They suggest that each member of the parent-child dyad influences the other's behavior. Crockenberg and Leerkes (2000) stated that mothers develop a gradual shift from initiator to responder during interactions over time, as infants become children. This shift is a natural adaptation of the mother's interactive behavior to their infants' needs as they become able to express their needs and desires.

Infants and young children with severe physical limitations have difficulties expressing their play needs and interests since they have limitations in initiating conversations and play topics (Pennington & McConachie, 1999), are passive and not very responsive and compliant when they play (Barrera & Vella, 1987; Hanzlik, 1989; Lieberman et al., 1995). Thus, mothers may not have enough information from the infants to naturally shift their behaviors. This effect can also explain their tendency to be more directive and less responsive with their infants and children with severe motor impairment. This, in turn may result in children being ignored during the few attempts to initiate so that mothers stay in the role of initiators and children stay in the role of responders for a longer time than in dyads of mother-typically developing child. Thus, the cycle of reciprocity in the dyad is not fed by responsiveness. Mother-child interactions where the mother is not over-controlling and is responsive to the child's needs and interests have been related to the development of child's secure attachment with the mother, which in turn boosts development of the child's confidence in their ability to attain goals independently and to their autonomy, mastery motivation and task persistence (Crockenberg & Leerkes, 2000). Thus, the delay in the mother's behavior shift may play a role in the learned helplessness described in children with motor impairment (Harkness & Bundy, 2001).

Previous researchers have shown successful attempts to improve maternal interactive behaviors in children with cerebral palsy and other disabilities through programs and strategies centered on parents and caregivers (Mahoney & Perales, 2003; Mahoney & Powell, 1988). The intervention in the present study was child-oriented as the child was provided with a robot for playing. This study demonstrated a positive impact on maternal directiveness and responsiveness when the child becomes more playful during play interactions. The change was consistent in those mothers who were highly directive and less responsive during the baseline. The change during the intervention suggests that mothers adapted their behaviours, becoming more sensitive to children's needs and interests as children were able to be more active, to initiate play themes, to interact with objects, and to try to communicate what they wanted to do. In other words, during the intervention, as the mothers observed that children were able to control the environment using the robot and perceived improvement in their children's play performance and independence, mothers were more willing to allow children to explore and to follow the child's lead while being ready to help when needed. Thus, the circle of reciprocity in the dyad was fed with more responsive behaviors from each member of the dyad, which contributes to the development of a secure attachment in children (Marvin, et al., 2002).

Results in the follow-up suggest that the levels of children's playfulness and mother's behavior tended to return to the baseline levels in some participants. The achieved change might be boosted by the addition of mother-oriented interventions as a complement to the robotic intervention for future studies and interventions. Rehabilitation interventions towards promoting children's free play, in combination with interventions towards promoting children's secure attachment and, increasing responsiveness while decreasing excessive directiveness in parents may help to prevent children with severe motor impairment developing learned helplessness.

The fourth research question asked whether mothers' affect/animation changed during or following the intervention in comparison with the baseline. The results revealed that the level of maternal affect/animation did not significantly change visually or statistically during the intervention or during the follow-up compared with the baseline. Thus, it seems that the robot did not impact the mothers' level of affect/ animation.

The last topic of discussion regarding maternal behavior is other possible explanations, different than the child's behavior itself, for the maternal directiveness and responsiveness expressed by mothers during the study. Maternal behaviors toward their children and parenting style are determined by multiple forces that emanates from the child, the parent, and the social context (Belsky & Jaffee, 2006). The forces regarding the child were discussed above. Some aspects related to forces from the social context were measured in this study. The forces measured that emanate from the context in this research were: the perceived number of people providing support to the mother and her satisfaction with the support, assistance with parenting provided by others (in some cases it was mother's parents, in others the mother's husband), socio-economic status, contextual sources of stress, educational level, and hours out of the home.

Previous research has found an association between maternal responsiveness and mother's years of education in children with disabilities (Blacher, et al., 2013). In typically developing children, high levels of maternal directiveness are predicted by limited social supports, low levels of socio-economic status (SES), more working hours outside home, and the mother's personality type (i.e. extraversion, agreeableness, conscientiousness, neuroticism, openness) (Smith, 2010). According to Table 3.7 (see results) it is clear from the information that there are no readily apparent factors associated with mothers' interactions. As indicated in the Participant description section (see section 2.2.1.), sources of stress for the four mothers during the study were mainly associated with children's access to rehabilitation and educational services. Maternal personality type might have an impact but it was not measured in the present study. Thus, the only aspect that was consistent among the mothers was that the more playful children had the more responsive and less directive mothers.

4.3. Play performance and satisfaction with performance

The fifth and sixth research questions asked if there was a change in mothers' perceptions of the child's occupational performance in play and their satisfaction with the performance of children with CP following the intervention compared with the baseline. The play performance and satisfaction with the performance increased in all the children during the intervention and some carry over effects were perceived by mothers after the intervention. Most of the COPM scores improved more than two units during the intervention indicating that the change in those children’s identified problems areas was clinically relevant (Law, et al., 1998). Improvements in the children’s abilities identified by mothers were: attention and persistence with the activity, coordination and manipulation skills, posture, and communication. This is consistent with previous robotics studies where parents and teachers identified similar effects on children (Cook et al., 2011). MP03’s COPM score for P03’s manual ability was unexpectedly high (8 at baseline and follow-up and 9 at intervention) considering his severe motor limitations as assessed by the MACS.

4.4. Mothers’ Satisfaction with the intervention

The seventh research question asked how the mothers’ felt about the intervention. The results revealed that all mothers were satisfied with the intervention. For example, MP04 perceived that the robotic intervention helped P04 gain the skills necessary to control his power wheelchair. At the end of the intervention, all mothers stated that during the intervention their children were controlling the play, doing what they wanted, playing independently, choosing the activity, and interested in interacting with toys. These ideas are consistent with some of the characteristics of free play (Blanche, 2008; Parham, 2008; Skard & Bundy, 2008). Thus, mothers perceived that their children were independently playing, which is consistent with the ToP scores achieved by the children. In this way, the intervention might increase mothers’ value of play as well as their skills to play with their children.

4.5. Confounding events

Due to the study’s design, some confounding events could affect the results as the data collection was done over four months. P01 was very excited in session B6 because he received a wheelchair from the health care system, which could explain the high score in that session. His mother reported that the wheelchair increased outdoor activities in the neighborhood. For P02, a new formal caregiver started to assist her in the mornings beginning with session B3. She liked the new person but ToP scores were unaffected by this change. Prior to the study P03 had a hip dysplasia surgery. He resumed his rehabilitation process after session B5. He suspended the treatment before session I3 and resumed it again before session I5 continuing until the end of the study. The mother reported before starting session I5, that P03 was tired because he had a hard and painful session of physical therapy. P04 received a power wheelchair in session I5. In spite of reports that power mobility has a positive effect on social skills, indoor free play, and the outdoor interactive free play, no effects have been found in interaction with toys or objects and verbal interactions (Guerette, et al., 2013). Thus, the likelihood that power mobility confounded the results is low. However, the fact that P04 was excited about the new wheelchair in sessions I5 could affect the high score in that session. Because MP04 expressed at the end of the intervention that the robotic intervention helped P04 to acquire the basic skills to control the wheelchair she might have tended to direct his behavior to gain more skills during the intervention. In addition, some sessions were not conducted at the scheduled times because children had medical appointments. Specifically for P01 there were some restrictions from the rehabilitation institution. For example, children were scheduled to go out for a trip or to a swimming pool on some of the arranged days for the study; thus, it was necessary to change the session day or time. Consequently, changes in the original schedule in days or the arranged day but at a different time could affect the scores in some sessions. It seems that changes in the arranged time might have more impact on the scores than changes in the arranged days because the data corresponding to changes in the arranged days did not show unusual scores. For example, P03's session I10 was four hours earlier than the arranged time, and this was his lowest ToP score while session I9 was two hours later from the arranged time, and this was his highest ToP score.

4.6. Strengths of the project

Studies have claimed the need to develop strategies to promote free play in children with severe motor impairment (Blanche, 2008; Brodin, 2005; Gowen et al., 1992; Harkness & Bundy, 2001).The main novelty of the current research is that this is the first study that investigates the effect of a robotic intervention on free play of children with motor impairment. Based on the theoretical approach to play as self (Sutton-Smith, 2001), this study provided evidence that an inexpensive robotic system improved children's playfulness and decreased maternal directiveness during free play. Under this theoretical approach play is valued because of the enjoyment and fun that it provides to life. When children are engaging in free play and demonstrating playfulness, they develop a sense of mastery, motivation, self-control and self-competence (Skard & Bundy, 2008). The design and protocol were based in the observation of free play that allowed researchers to observe: 1) how children with severe motor impairment play when they are able to operate a robot for manipulating the environment; and 2) how mothers react when observing their children play independently. In the same way, mothers participating in this study had the opportunity to learn about their children's play skills and interests. This approach to play in children with disabilities is also consistent with the Let's Play model (Lane & Mistrett, 2002) that states that outcomes in interventions for children with disabilities and their families should include play and playfulness by using assistive technology.

Conducting the study under a different theoretical approach such as pre-defined play activities, might have missed meaningful information. For example, mothers would not have had the opportunity to learn about their children's play. Previous research with robotics had been based mainly in an approach to play as a medium of intervention in rehabilitation (Besio, et al., 2008; Robins, et al., 2008). Structured and semi-structured activities were used to understand the cognitive, perceptual and physical skills required for operating a robotic system (Cook, et al., 2011; Cook, et al., 2012), and the perception of teachers, parents and therapists of the potential use of robots as part of the rehabilitation process in children with motor impairments (Besio, et al., 2013; Cook, et al., 2011; Cook, et al., 2005). Researchers who have proposed play scenarios or scripts (Robins, et al., 2008; Besio, et al., 2008) have recently found that therapists and children with cerebral palsy tried to go beyond the predefined play activities (Besio, et al., 2013). This may indicate that pre-defined activities allow observations of different aspects of children's performance but not child-directed play.

Previous studies of the interaction between mothers and children with disabilities have tested interventions centered on parents or caregivers in order to improve their parental behaviors. Another novel aspect of this study is that the intervention was child-oriented but still had an effect on maternal directiveness and responsiveness for some mothers. Thus, this study provides knowledge about the power of assistive technology not only to allow children with motor impairment to interact with and impact on their physical environment, but also to impact children's social context (mothers' directiveness), which in turn fosters children's development.

Other strengths of the project are uniformity of the sample with regard to gross motor function and manual ability, and high treatment integrity and inter-rater reliability. In addition, this study revealed some possible reasons for more directiveness and low responsiveness during play in mothers of children with severe motor and communicative impairments. Since the study was conducted in children's natural environments (home and rehabilitation centre), the application of the research results to community settings is feasible.

The collection of various types of data (video analysis, interviews, standardized questionnaires, and self –perception assessment) provided a holistic picture of the impact of robots on the play experience of children with severe motor impairment due to cerebral palsy. Finally, the protocol allows replication of the study with children with cerebral palsy in other contexts such as children who have had more exposure to assistive technology or in societies where play has a different value by parents.

4.7. Limitations of the study

The main limitation of this study is that the researcher was not blinded to the study phases because she collected the data and scored the sessions. The second rater was blinded to the phases for the baseline and the follow-up measures; however, there were sessions when the participants revealed aspects of the phase. For example, in some of the follow-up sessions the mother or the child asked or commented about their experience with the robot. In addition, the second raters who scored the ToP and the MBRS, who assessed the treatment integrity for the 20 randomly selected sessions, and who assessed the validity of the interviews knew the researcher but they did not know the study's objectives and hypotheses. These situations are the result of restricted availability of raters trained in the measures (ToP and MBRS) or who had a basic knowledge about research and who were proficient in English and Spanish.

Another limitation is associated with the use of inexpensive technology. The Lego Invention robots have many advantages, but they are not 100% accurate in their movements. Consequently, children with the highest cognitive level expressed momentary disappointment when the robot did not take the exact direction expected. This has been reported in previous research (Encarnção et al., 2012). Another problem was the inconsistency of the infrared in some sessions and children expressed frustration when the infrared signal did not reach the robot sensor. A robot wheel fell off in some sessions and it took a while for the mother to notice it. Children were confused when it happened because they noticed that the robot was not behaving as they expected. The Lego robot moves in two dimensions with limitations for moving in three dimensions; thus, it could not do everything children wanted to. One example is P01 wanted the robot to climb the therapeutic stairs and got frustrated when he realized that the robot could not do it.

The scoop used was another technical limitation, it broke off the robot when children tried to push the biggest toys or when the robot hit the wall. When the scoop came off the mothers had to provide extra assistance to the child by attaching the scoop to the robot. P04 would be able to use six switches in order to make a gripper open and close but this option was not available. Having more options would provide more independence for his play. For future research, an assessment of the ability of children to operate a gripper via added switches should be considered.

Another limitation is that the measures used are not measures of mother-child reciprocity; thus the child and mother's behaviors were scored separately. Using measures of reciprocity could provide more information about changes in the interaction of the mother-child dyad in the different phases of the study. For example, the fact that two mothers did not show changes in maternal responsiveness with the intervention could be due to a ceiling effect; using measures based on frequencies of the responsiveness might reveal significant changes in their behavior.

Another limitation is the fact that for P01 and MP01 the study was not conducted at home. Conducting the study in different environments could have an impact on the results. For example, P01 and MP01 took a taxi to each session, which was new for them. P01 was very excited about it and incorporated the situation about the taxi in his play, e.g., "I am the taxi driver", "there is a traffic jam there". Since all taxis in Colombia are yellow as was the robot color, it was easy for him to find the similarity between the taxi and the robot, which helped to improve his pretend play. Similarly, his motivation about the whole experience of taking a taxi could have an impact on his motivation with the intervention. It is important to take into account that children with cerebral palsy are more playful at home than in other community environments (Rigby & Gaik, 2007). The rehabilitation centre imposed more restrictions for conducting the sessions in the arranged time and days than those that normally occurred in the other participants' family life.

This study met the minimal requirement of the number of subjects for a multiple baseline design (three participants), but the effect of the intervention is based on a small sample of four children with cerebral palsy and their mothers. Replications of the study with more participants could help to achieve greater generalization of results.

Another limitation is that the MBRS was not scored during the entire 15 minutes of play. This responded to the MBRS's developed recommendation of scoring seven minutes in order to achieve high inter-rater reliability. This decision may generate a negative impact on the study's validity. However, according to the MBRS's developer and previous studies, seven minute long observations are enough to asess the mother's interactive behaviors (Mahoney, 2008).

Another limitation is that no inter-rater reliability was done for the TOES. For the current study, the TOES was not a dependent variable but it was used as part of the procedures for assesing the treatment integrity. However, the TOES has acceptable values of inter-rater reliability assessed by how data fit the Rasch model (Bronson & Bundy, 2001).

The study was conducted in Spanish using measures (e.g. ToP, MBRS, IIP, PTI-2) that were originally developed in English. This may be seen as a limitation. The MBRS has not been used with Spanish speaking parents (G. Mahoney, personal communication, April, 30, 2014). The IIP is available in English and French. However, the ToP is valid for Hispanic children in United States and Central America (Skard & Bundy, 2008) and the SSQ-6 has a version in Spanish (Marrero Quevedo & Carballeira Abella, 2010).

4.8. Clinical implications

Literature on play consistently asserts that play is critical for children's development. Similarly, literature in the field of rehabilitation is consistent regarding children with severe motor impairment due to CP having difficulties engaging in free play. As a result, they miss many opportunities to develop motor, social, emotional and cognitive skills that typically developing children naturally develop through free play. In spite of the overt need of strategies that promote engagement of children with CP in free play, the evidence for the effectiveness of these strategies is minimal. Usually families of children with disabilities have concerns about the type of toys and family activities that are the best options for promoting development (Munier et al., 2008). The minimal evidence about the effective strategies for promoting free play in children with CP may result in limitations in the useful advice therapists can provide to families.

The current study provides strong evidence for therapists that inexpensive Lego robots can be used for children with CP to engage in free play. This study demonstrated that an adapted Lego robot allowed children with severe motor impairment due to CP to play in the way they want. Since engaging in free play has benefits for children's development, this study's findings are of importance for families and therapists. Adapted Lego robots can promote development in children with severe cerebral palsy through free play. Thus, families of children with cerebral palsy can implement the Lego-based intervention in the family routines for promoting their children's play. Play itself is an occupational therapy outcome. Lego robots may be also used as part of interventions aimed at promoting free play in children with CP. In cases in which a Lego robot is affordable for the family, therapists may advise them that robot-based play can assist family play activities. The results of the current study may help occupational therapists when orienting families about effective strategies for their children to engage in free play at home.

A robot may increase the frequency and quality of object play activities that children with motor impairments perform with their families. Mothers in the present study expressed that it was easier for them to know their child's play desires and interests when the child played with the robot. Lego robots have the potential to facilitate the interaction of the mother with a child who has CP. If mothers perceive that playing with their children is easier when they have a Lego robot, it is likely that mothers will play more frequently with their children and try to involve other family members in the play activities. This finding is useful for planning rehabilitation programs for integrating play in the lives of children with CP.

Some mothers in the current study provided valuable information about the reasons for their tendency to be highly directive and minimally responsive during the baseline. Mothers felt uncertain that they knew how their children wanted to play, felt that they needed to manipulate the toys because of their children's motor impairments, and tended to model therapeutic activities instead of following the children's lead during free play. Thus, intervention in rehabilitation oriented towards modifying these kind of maternal trends can improve children's engagement in free play at home.

4.9. Future research

The results of this research provide guidelines for future research. This study demonstrated that Lego robots increase playfulness in four children with severe motor impairment due to CP. A logical future study is to replicate the design with a larger sample of children with more children with and without cognitive delays. A large sample including children from different cultures would improve the level of evidence provided by the present study.

The fact that after the intervention the playfulness showed retention of levels achieved during the intervention in three children provide support for future research. On a theoretical level, playful interactions with objects promote the development of mastery motivation, sense of competence, and self-efficacy. In the same way playfulness is related to the development of self-directed behaviors. Future studies can investigate the effect of the robotic intervention on these constructs which are critical to promote in children with CP.

Mothers in this study reported improvement in their children's attention, persistence with the activity, coordination, manipulation, posture, and communication. Those skills were not measured in the present study and future research could investigate the effect of the robotic intervention on these skills. Comparative studies can also be conducted in order to know differences between outcomes related to those skills during conventional occupational therapy and physical therapy sessions versus sessions using the robot during play activities. Other outcomes of interest could be cognitive development, social skills, and self-care activities

The robot did not appear to impact pretend play but revealed some pretend play performed by children using the robot. Future studies can assess pretend play in children with motor impairment using the robot. These studies can include both the use of robots to assess and promote pretend play in children with CP.

After some intervention sessions some children's relatives (sister and cousins) spontaneously initiated play activities with two participants. Participants were highly motivated during those short interactions. Another option for future research could be to conduct exploratory studies about interactions between the child with CP who is able to use a robot and his siblings, relatives or peers.

The literature about the interaction between children with cerebral palsy and their mothers is not abundant. Since this study provided valuable insights about how maternal behaviors change in response to children's behaviors, another area of interest could be to conduct comparative studies of the maternal behavior between young children who are exposed to robotic intervention and young children who are not. Longitudinal studies can provide stronger evidence about how this type of assistive technology can transform the maternal behaviors over time as children grow up.

Similarly, among the reviewed papers, no study investigated mother-child with CP interaction in low-income countries. Due to cultural differences the pattern of interaction might vary from what the literature reports in high-income countries. Thus, research can be conducted in order to know the patterns of interaction between children with cerebral palsy and their mothers in low-income contexts and development of strategies for increasing mother-child interaction in children with cerebral palsy in these contexts. Comparative studies can be conducted in order to know if a training program for improving maternal interactive behavior is more effective than the robot approach described in this study.

5. Conclusions

Literature in the field of cerebral palsy calls for the development of interventions and strategies in order for children with CP to engage in play. This is the first study that investigated the effect of a robotic intervention on free play for children with CP. This study demonstrated that Lego robots help children with severe motor impairments due to CP to engage in free play and demonstrate playfulness. All children in this single-case study showed significant improvement in their playfulness when using a robot for play. All children used the Lego robot to interact with their toys so it served as a tool for children with severe motor impairment to explore, interact with and impact their physical environment in a playful manner. This finding provides support to the play theories and approaches that explain play from a psychobiological perspective (optimal arousal) (Burghardt, 2005; Coplan, Rubin, & Findlay, 2006), and from a cognitive and social perspective (Reilly, 1974; Skard & Bundy, 2008; Sutton-Smith, 2001). It was found that the robot allowed children with severe motor impairment to engage in a diversive exploration of their toys while they expressed playfulness. The interaction was driven by the question "what can I do with these objects using the robot?" As the intervention progressed children had the opportunity to practice their skills; to experience self-control and intrinsic motivation; and to demonstrated persistence, concentration, and creative problem solving during free play.

After the intervention children's playfulness showed carryover of levels achieved during the intervention in three children with a tendency towards the baseline levels. This finding encourages future research exploring strategies to maintain improvements in playfulness over time. Previous studies that found changes in playfulness in children with cerebral palsy after interventions did not explore retention of the effects over time (Okimoto et al., 1999; Reid, 2004).

Literature in the field of interactions between mothers and their children with CP calls for the need to develop strategies to promote maternal behaviors that foster child's development. The current study is the first that investigated how mothers react when children with severe motor impairment are able to engage in free play. This study found that the robotic intervention improved the mothers' perception of their children's play performance and increased their satisfaction with their children's play performance. The study's results are inconclusive about the effect of the robotic intervention on mothers' directiveness and responsiveness. However, the results indicated that those mothers who were highly directive and minimally responsive during the baseline, improved their maternal behaviors during the intervention. Those mothers adapted their maternal behaviors as children expressed more playfulness by being active, engaged, and motivated while initiating interactions during free play. This finding encourages future research exploring how changes in maternal perception of children's performance may influence maternal behaviors.

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Appendixes

Appendix A: Ethics application approval University of Alberta

Approval

Date:	September 11, 2012
Study ID:	Pro00033318
Principal Investigator:	Albert Cook
Study Title:	The effect of a robotic intervention on the free play experience of children with severe cerebral palsy
Approval Expiry Date:	September 10, 2013

Thank you for submitting the above study to the Health Research Ethics Board - Health Panel . Your application, including revisions received September 6, 2012, has been reviewed and approved on behalf of the committee.

A renewal report must be submitted next year prior to the expiry of this approval if your study still requires ethics approval. If you do not renew on or before the renewal expiry date, you will have to re-submit an ethics application.

Approval by the Health Research Ethics Board does not encompass authorization to access the patients, staff or resources of Alberta Health Services or other local health care institutions for the purposes of the research. Enquiries regarding Alberta Health Services approvals should be directed to (780) 407-6041. Enquiries regarding Covenant Health should be directed to (780) 735-2274.

Sincerely,

Colleen Norris, Ph.D.
Associate Chair, Health Research Ethics Board - Health Panel

Note: This correspondence includes an electronic signature (validation and approval via an online system).

Notification of Approval - Amendment

Date:	May 9, 2013
Amendment ID:	Pro00033318_AME3
Principal Investigator:	Albert Cook
Study ID:	MS2_Pro00033318
Study Title:	The effect of a robotic intervention on the free play experience of children with severe cerebral palsy
Approval Expiry Date:	September 10, 2013

Thank you for submitting an amendment request to the Health Research Ethics Board - Health Panel. The following has been reviewed and approved on behalf of the committee:

- Add Bogota, Columbia as another study site. As indicated in your amendment form, local ethics approval will have to be obtained. Any changes requested of the Columbia REB should be communicated back to this board. Please append a copy of the Columbia approval upon its receipt.

Note: Approval for an amendment does not change the original approval date.

Sincerely,

Dr. Glen J. Pearson, BSc, BScPhm, PharmD, FCSHP
Associate Chair, Health Research Ethics Board - Health Panel

Note: This correspondence includes an electronic signature (validation and approval via an online system).

Appendix B: Ethics application approval Bogota, Colombia

COMITÉ DE ÉTICA EN INVESTIGACIÓN (CEI)
ESCUELA DE MEDICINA Y CIENCIAS DE LA SALUD (EMCS)
UNIVERSIDAD DEL ROSARIO

UNIVERSIDAD DEL ROSARIO

Acreditación institucional de alta calidad
Ministerio de Educación Nacional
Evaluación internacional
Asociación Europea de Universidades

CEI- ABN026- 000199

Bogotá, 22th July 2013

Doctor
ADRIANA RIOS RINCÓN
Principal Investigatore
Estudio: "EFFECTS OF A ROBOTIC INTERVENTION ON THE FREE PLAYING EXPERIENCE OF CHILDREN WITH SEVERE BRAIN PALSY"
Ciudad

On 18th July 2013, 7:00 AM, the Ethics Research Committee of the School of Medicine and Health Sciences, Universidad del Rosario, met at the Quinta de Mutis Campus, and considered for approval the study: "Effects of a robotic intervention on the free playing experience of children with severe brain palsy".

The following documents were taken into account, in accordance to a previous Committee's request:

- Informed Consent Form – Mother
- Informed Consent Form - Letter of Information
- Informed Consent Form – Child

The meeting was attended by the following members of the Committee (minimum quorum for approval is five members):

- Ramón Fayad, Physicist, President.
- Gloria Cecilia Montero, Social Worker, Secretary.
- Sergio Andrés Amaya, Physician and Psychologist.
- Ximena Palacios, Psychologist.
- Laura del Pilar Rico, Physician.
- Pablo Moreno, Social Worker.
- Pablo Andrés Bermudez, Medicine Student.

After deliberation, the protocol in mention was approved by Act No. 240.

Carrera 24 No. 63C-69 Quinta Mutis -
Teléfono: 3474570 Ext. 380-249
Fax: 3474570 Ext. 210

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UNIVERSIDAD DEL ROSARIO

At periods not less than bi annually and at the Study Ending, the Principal Investigator is requested to provide updated reports about this Study.

This Committee deliberates under the legal and ethical guidelines of the Republic of Colombia, according to Resolutions 008430/1993 and 002378/2008 of the Ministry of Social Protection. It also follows the guidelines contained in the Declaration of Helsinki (Seoul, Korea, 2008) and the World Conference on Harmonization for Good Clinical Practice.

Best regard,

RAMÓN FAYAD NAFFAH
President

Carrera 24 No. 63C-69 Quinta Mutis -
Teléfono: 3474570 Ext. 380-249
Fax: 3474570 Ext. 210

Appendix C: Recruitment material – Poster

Robots
Research Project!!!

Researcher: Adriana Rios
Supervisors: Dr. Al Cook & Kim Adams

- **Purpose:** We want to investigate the effect of a robot-based intervention on the child's play and mother-child interaction.
- **Task:** Free play sessions at home. The child will play with his or her own toys and with his or her mom. After some sessions the child will be trained in how to operate the robot to manipulate the toys.
- **Participant criteria:**
  - –Children between 4 and 8 years of chronological age.
  - –Child has a diagnosis of cerebral palsy with impairment in upper limbs.
  - –Child does not have a significant visual or hearing impairment.
  - –Children who understand English.
  - –Children who have the ability to express choices and answer yes/no.

If you know of anyone who meets this criteria and would be interested in participating please contact:

Adriana Rios Rincon
Email: aros@ualberta.ca
Phone: (780) 492-5422

Adriana Rios Rincon
Email: aros@ualberta.ca
Phone: (780) 492-5422

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Email: aros@ualberta.ca
Phone: (780) 492-5422

Appendix D: Recruitment material - Parents' info letter

The effect of a robotic intervention on the free play experience of children with severe cerebral palsy

Investigators:

A. Rios Rincon (PhD student, Faculty of Rehabilitation Medicine)
A. Cook (PhD student's Supervisor. Speech Pathology and Audiology Department)
K. Adams (PhD student's Co-supervisor. Faculty of Rehabilitation Medicine, Glenrose Rehabilitation Hospital)

Purpose: To investigate the effect of a robot-based intervention on the child's play and mother-child interaction.

Background: Free play is important for children's development. Motor skills are affected in children with cerebral palsy. In some children these problems affect manipulation. Without manipulation, children have difficulties engaging in free play-play directed by the child. It is much more difficult for these children to learn and to develop because they can't interact with the environment. Research has shown that robots can serve as a way for children to engage in free play with objects.

Procedures: The total length of the study will be from 8 up to 14 weeks. There will be two or three sessions per week. The length of the each session will be 15 minutes. This study will have three phases. During the entire study the child will play with his or her mother at home with his or her own toys. During the first and the third phases your child and his or her mother will only play with their own toys. During the second phase a robot will be available for the free play sessions. The length of the phases are individualized for each child. The researcher will inform you when the second and the third phases are ready to start. Before starting the second phase, your child will be trained in the use of the robot. All sessions will be videotaped. The videotapes will be analyzed after sessions. Child and mother will be videotaped because their interaction is important for this study.

Benefits: Children have fun when they use robots for play. They also develop skills that help language development and learning. The results of this study will support interventions that promote play in the life of children with disabilities. Children and mothers involved in this project will have the opportunity to play together using a robot. This may increase mothers' skills to play with their child.

Risks: Your child may get tired during the task. Breaks will be given as needed. The robot is battery operated and there is no danger of electrical shock. The robot is small and lightweight and will not hurt the child if it does contact him or her.

Confidentiality: All the information you provide will be kept confidential. We may use the video tapes or data derived from our analysis of the results for teaching or research presentations. We will only report group data and will not identify any specific children in any presentation we give. The information will be kept for at least five years after the study has been completed. It will be kept in a safe place and will be only be available to the researchers.

Freedom to Withdraw: You are free to refuse to participate or withdraw from this study at any time. You do not have to give a reason and it will not affect your child's program or treatment in any way.

Additional Contact: If you have any questions about the study please contact: Dr. Al Cook (Phone 780-492-8954, Fax 492-1626, e-mail - al.cook@ualberta.ca) Faculty of Rehabilitation Medicine, University of Alberta.

If you have any concerns about any aspect of this study please contact Dr. Tammy Hopper, Associate Dean (Graduate studies and Research), Faculty of Rehabilitation Medicine, University of Alberta at (780) 492-0836. Dr. Hopper has no direct relationship to this study.

If you have concerns about the conduct of the research, can you contact the Ethics Office at 780-492-2615. This office is independent of the researchers.

Appendix E: Child's consent form

Consent Form

Title of Project: The effect of a robotic intervention on the free play experience of children with severe cerebral palsy

Investigators:

A. Rios Rincon *(PhD student, Faculty of Rehabilitation Medicine)*
A. Cook *(PhD student's Supervisor. Speech Pathology and Audiology Department)*
K. Adams *(PhD student's Co-supervisor. Faculty of Rehabilitation Medicine, Glenrose Rehabilitation Hospital)*

To be completed by the research subject' parent:

Do you understand that your child has been asked to be in a research study?	Yes	No
Have you read and received a copy of the attached Information Sheet?	Yes	No
Do you understand the benefits and risks involved in your child taking part in this research study?	Yes	No
Have you had an opportunity to ask questions and discuss this study?	Yes	No
Do you understand that you are free to refuse to participate or to withdraw from the study at any time without giving a reason and without negative consequences?	Yes	No
Do you understand the study will be conducted at you and your child's home?	Yes	No
Do you understand that your child will begin to use the robot between the third and the sixth week?	Yes	No
Do you understand that the researcher will determine the moment in which your child will begin to use the robot?	Yes	No
Has the issue of confidentiality been explained to you? Do you understand who will have access to your child's records?	Yes	No
Do you consent to have your child videotaped for research purposes?	Yes	No
Do you consent to have your child videotaped for educational purposes?	Yes	No

This study was explained to me by: ______________________________

I agree to allow my child to take part in this study.

______________________________ ________________
Signature of Parent Date

____
Printed Name

____
Name of Child

I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate.

___________________________________ __________________
Signature of Investigator or Designee Date

Appendix F: Child's assent form

ASSENT FORM

Title of Research Study The effect of a robotic intervention on the free play experience of children with severe cerebral palsy

Investigators:

A. Rios Rincon *(PhD student, Faculty of Rehabilitation Medicine)*
A. Cook *(PhD student's Supervisor. Speech Pathology and Audiology Department)*
K. Adams *(PhD student's Co-supervisor. Faculty of Rehabilitation Medicine, Glenrose Rehabilitation Hospital)*

We would like you to participate in a research study in which you will play with a robot. Five children like you will take part in this study.

What will you have to do?: If you and your parents agree to take part, we will ask you to play at your house with some of your toys. You will play with your mother. We will teach you how to control a robot. Then you can use the robot when you are playing with your toys. This is the robot you will play with (the researcher shows the robot to the child).

Will it help?: You may enjoy playing with the robot.

Will it hurt?: No, it will not hurt.

Can you quit?: You don't have to take part in the study at all, and you can quit at any time. No one will be mad at you if you decide you don't want to do this, or if you decide to stop. You should tell your parents or any of the researchers if you want to stop.

Who will know?: No one except your parents and the researchers will know you're doing this unless you want to tell other people. Your name and your information won't be seen by anyone except the researchers during the study.

Your signature: We would like you to sign this form or make a verbal or non-verbal sign that you want to participate. Your mom or dad will be asked to sign another form agreeing for you to take part in the study.

Do you have more questions? You can ask your mom or dad about anything you don't understand. You can also ask to the professors Al Cook and Kim Adams. Professor Cook's phone number is 780 492-8954. Professor Adam's phone number is: 780 492-0309.

I agree to take part in the study.	<signature of research participant>	<date>
	<signature of witness>	<date>
	<signature of investigator>	<date>

Appendix G: Mother's consent form

Consent Form

Title of Project: The effect of a robotic intervention on the free play experience of children with severe cerebral palsy

Investigators:

A. Rios Rincon *(PhD student, Faculty of Rehabilitation Medicine)*
A. Cook *(PhD student's Supervisor. Speech Pathology and Audiology Department)*
K. Adams *(PhD student's Co-supervisor. Faculty of Rehabilitation Medicine, Glenrose Rehabilitation Hospital)*

To be completed by the research subject:

Do you understand that you have been asked to be in a research study?	Yes	No
Have you read and received a copy of the attached Information Sheet?	Yes	No
Do you understand the benefits and risks involved in you taking part in this research study?	Yes	No
Have you had an opportunity to ask questions and discuss this study?	Yes	No
Do you understand that you are free to refuse to participate or to withdraw from the study at any time without giving a reason and without negative consequences?	Yes	No
Do you understand the study will be conducted at your home?	Yes	No
Has the issue of confidentiality been explained to you? Do you understand who will have access to your child's records?	Yes	No
Do you consent to be videotaped for research purposes?	Yes	No
Do you consent to be videotaped for educational purposes?	Yes	No

This study was explained to me by: ______________________________

I agree to take part in this study.

______________________________ ________________
Signature of the participant (mother) Date

____
Printed Name

I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate.

___________________________________ __________________
Signature of Investigator or Designee Date

Appendix H: Treatment Integrity Check list

Treatment Integrity Check List – Baseline and Follow-up sessions

Participant: __________________ Date: _________________________________

Aspect	Yes	Not	N/A
The researcher asked how does the child and the mother feel that day. Child: Good Regular Bad Mother: Good Regular Bad			
The set the toys that will be used are the same			
The child is placed on the floor using the positioning equipment in the same position for all phases. The child's position is:______________________			
For all phases there are a space of 3 to 4 feet between the child and the toys			
The toys are located next to each other so that the child can see them all			
The physical space in which the study is conducted is the same (report any change and the reason).			
Other members of the family and pets remain in a different room and quiet while the sessions are carried out.			
The session is conducted within the days arranged (__________ and _________)			
The session is conducted in the time arranged (__:__)			
The session is fifteen minutes long			
The same verbal instruction is given to the mother by the researcher: *"Play with (child's name) as you typically do. I will not evaluate any particular skill. I only want to observe how you play. I would like you to play for 15 minutes."*			
The same verbal instruction is given to the child by the researcher: *"You can play with any of these toys that you choose. Your mom will play with you"*			
The researcher intervene in the mother-child interaction during the session (the researcher must not interfere)			
The researcher applies the TOES at the end of the session			
The researcher asks events that have been different from the family routines and habits during the preceding days reported by the mother, the child or the family. Events:			
Observations:			

Treatment Integrity Check List – Intervention sessions

Participant: _________________ Date: ________________________________

Aspect	Yes	Not	N/A
The researcher asked how does the child and the mother feel that day. Child: Good Regular Bad Mother: Good Regular Bad			
The set the toys that will be used are the same			
The switches are functioning and are well placed (for the intervention phase)			
The robot is functioning well in its movements			
The batteries are working			
The remote control IR signals is functioning			
The child is placed on the floor using the positioning equipment in the same position for all phases. The child's position is:___________________________			
For all phases there are a space of 3 to 4 feet between the child and the toys			
The toys are located next to each other so that the child can see them all			
The physical space in which the study is conducted is the same (report any change and the reason).			
Other members of the family and pets remain in a different room and quiet while the sessions are carried out.			
The session is conducted within the days arranged (__________ and __________)			
The session is conducted in the time arranged (__:___)			
The session is fifteen minutes long			
The same verbal instruction is given to the mother by the researcher: *"Play with (Child's name) as you typically do. I am not interested in observing how well (child's name) controls the robot. I will not evaluate any particular skill. I only want to observe how the robot is part of your play. I would like you to play for 15 minutes."*			
The same verbal instruction is given to the child by the researcher: *"You can play with any toys that you want and with the robot. Your mom will play with you"*			
The researcher intervene in the mother-child interaction during the session (the researcher must not interfere)			
The researcher applies the TOES at the end of the session			
The researcher asks events that have been different from the family routines and habits during the preceding days reported by the mother, the child or the family. Events:			
Observations:			

Appendix I: Treatment Integrity Check list: Assessment second rater

Treatment Integrity Check List Baseline and Follow-Up Sessions

Second rater initials: ____________

Participant: ______________ **Session #: _________** **Date of assessment: ___________________________**

Aspect	Yes	U	No	Comments if "No" chosen
Did the researcher ask how do the child and the mother feel the session day?				
Were the set the toys that used the same?				
Was the child placed in the same position? The child's position was:_____________				
Was there a space of 3 to 4 feet between the child and the toys at the beginning of the session? (For all phases)				
Were the toys located next to each other so that the child could see them all?				
Was physical space in which the study was conducted the same?				
Did other members of the family and pets remain in a different room and quiet while the session was carried out?				
Was the session conducted within the days arranged? Write the name of the week day (e.g. Monday) : _______________				
Was the session conducted in the time arranged? Write the starting time __:___				
Was the session is fifteen minutes long or longer?				
Did the researcher provide the same verbal instruction to the mother?: *"Juegue con (nombre del niño) como ustedes juegan generalmente. Yo no voy a evaluar ninguna habilidad en particular. Yo solo quiero observar como ustedes interactúan durante el juego. Van a jugar por 15 minutos"*				
Did the researcher provide the same verbal instruction to the child?: *"Puedes jugar con todos los juguetes que hay aquí. Tu mama va a jugar contigo"*				
Did the researcher intervene in the mother-child interaction during the session?				
Did the researcher ask events that have been different from the family routines and habits during the preceding days reported by the mother, the child or the family?				

N/A: Not applicable.
U= Unassessable: It was not possible to determine using the videos and the sheets.

Treatment Integrity Check List Interventions Sessions
Second rater initials: ___________

Participant: ______________ **Session #: _________** **Date of assessment: ___________________________**

Aspect	Yes	U	No	Comments if "No" chosen
Did the researcher ask how do the child and the mother feel the session day?				
Were the set the toys that used the same?				
Were the switches functioning and are placed in the same location?				
Was the robot functioning well in its movements?				
Were the batteries working?				
Were the remote control IR signals functioning?				
Was the child placed in the same position? The child's position was:______________				
Was there a space of 3 to 4 feet between the child and the toys at the beginning of the session? (For all phases).				
Were the toys located next to each other so that the child could see them all?				
Was physical space in which the study was conducted the same?				
Did other members of the family and pets remain in a different room and quiet while the session was carried out?				
Was the session conducted within the days arranged? Write the name of the week day (e.g. Monday) : _______________				
Was the session conducted in the time arranged? Write the starting time __:___				
Was the session is fifteen minutes long or longer?				
Did the researcher provide the same verbal instruction to the mother?: *"Juegue con (nombre del niño) como ustedes juegan generalmente. Yo no estoy interesada en que tan bien (nombre del niño) controla el robot. Yo no voy a evaluar ninguna habilidad en particular. Yo solo quiero observar como el robot es parte de su juego. Van a jugar por 15 minutos"*				
Did the researcher provide the same verbal instruction to the child?: *"Puedes jugar con todos los juguetes que hay aquí y con el robot. Tu mama va a jugar contigo"*				
Did the researcher intervene in the mother-child interaction during the session?				
Did the researcher ask events that have been different from the family routines and habits during the preceding days reported by the mother, the child or the family?				

N/A: Not applicable. U= Unassessable: It was not possible to determine using the videos and the sheets.