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From Infancy to Early Childhood: The Role of Augmentative Manipulation Robotic Tools in Cognitive and Social Development for Children with Motor Disabilities

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Abstract. Motor experience plays a critical role in cognitive and social development. Developmental research has identified the major role of motor experience through manipulation and locomotion on the cognitive development of typically developing children. Children with physically disabilities cannot independently explore the environment and manipulate objects, and their motor impairments limit their opportunities for developing cognitive and social skills. Assistive technologies can provide the means for children with disabilities to independently interact with their physical and social environments. Assistive robots can provide children with disabilities with opportunities for object manipulation. This paper describes research using robots to understand and promote cognitive and social development of children with physical disabilities.

1 Introduction

The study of development has demonstrated the influence of early experiences and the relationship between physical and cognitive development [1]. Several approaches to typical development emphasize the crucial role of motor experience [2]. Because of this strong relationship it has been suggested that a lack of motor experience can result in cognitive and perceptual delays [3]. One of the motor experiences that can assist in cognitive development is manipulation, but a physical disability can limit the child's ability to physically manipulate objects [4], which can affect the quality of their play and learning skills [5]. Motor impairments can have persistent other psychosocial development effects, e.g., poor motivation, apathetic behaviour, poor self-initiative, feelings of helplessness [1]. Assistive technologies (AT) can provide opportunities for environmental exploration by young children with disabilities [6]. Assistive robots can facilitate object manipulation to enhance development and learning, and provide opportunities for the child to play and reveal cognitive understanding [7].

2 Cognitive Development

Several developmental theories have held that it is through motor experience and exploration that children develop cognitive and perceptual skills [8]. Physical manipulation has been identified as a critical motor behaviour enabling the acquisition of learning skills, emergence of symbols, referential communication and the understanding of relations between objects [2], [9]. Piaget viewed motor experience and manipulation as the source of cognitive development [10]. Motor experience allowed the child to explore, manipulate and transform his environment assimilating his experiences and expanding his cognitive skills [11].
The approach of Vygotsky differs in the consideration of the influence of environmental interactions on the child's use and understanding of objects [12]. Cognitive development is mediated by social interactions with the environment [12]. Object manipulation and tool use are influenced by the way adults and peers use objects in a particular context and how they respond to a child's exploration of a particular object. The adult observes the child perform the action and provides feedback and the child observes and imitates the use of objects, therefore how he relates to objects depends on the context [13]. Piaget's and Vygotsky's approaches to the study of cognitive development both highlight the critical role of knowledge construction by the child and the relation between motor experience and cognition

[14]. Due to their physical impairments, children with disabilities can lose opportunities to meaningfully explore objects and access the environmental information necessary to stimulate and enhance their cognitive development.

3 Play

Another developmental domain that can be compromised for children with physical disabilities is play. Play has been described as a complex and elusive concept difficult to define [15]. The most common traits of play are: 1) intrinsic motivation or autotelic; 2) process rather than product oriented; 3) enjoyment and pleasure; 4) active engagement and internal control; and, 5) suspension of reality [15].

Play is the most prevalent activity in childhood and has an instrumental role in child's development [16]. Playing provides the opportunity to discover and test capabilities, try-out objects, make decisions, comprehend cause and effect relationships, and understand consequences [17]. During free play children also learn through creative problem solving [15], [18], learn how to interact with objects and people [19], and experience a sense of internal control [15] and mastery [3]. Children with motor impairments may suffer from play deprivation as a direct consequence of their disabilities [17]. Physical impairments may affect the ability to actively access and explore the environment, manipulate objects, and communicate about the experiences [20]. Play deprivation can generate anxiety, frustration and passivity in children, which often leads to secondary disabilities [17] that decrease the child's sense of self-efficacy, self-confidence, satisfaction and well-being [21], and ultimately learned helplessness [1]. All of these factors also limit the child's future functioning in educational, community and work contexts [17].

4 Assistive Robots: Tools for Cognition and Playfulness

Early exposure to assistive technology for children with disabilities has shown that it can provide access to meaningful early experiences [22], [23]. AT allows these children to engage in more and different social, cognitive and communicative activities by increasing, maintaining, improving or compensating for their functional capabilities [24]. We are currently conducting studies on the use of robots as augmentative manipulation tools and their impact on early infant cognition and children's play and playfulness. Assistive robots can be used as a tool by children with disabilities since the motor control requirements are minimal and flexible depending on the child's skills [7]. Tool use is directly related to critical cognitive skills such as understanding of causal relations and interactions between objects [25]. Tool use promotes cognitive skills by developing an understanding of spatial knowledge, i.e., how objects can be handled or manipulated to serve a goal [26]. Assistive robotics provides a means for children that have difficulty interacting with objects using their hands to assist their manipulation and their independent manipulation of objects, promoting exploration and discovery, thus impacting cognitive development [27].

Children with motor impairments share play characteristics such as curiosity, sense of humor, pleasure and spontaneity with typically developing children [16], but their motor limitations constrain play-based interaction. Assistive robots can allow children with motor impairments to engage in free play. The robot allows the child to independently engage in free play with objects answering the question: *What can I do with this object by using the robot?* The interaction can promote the child's playfulness. Some elements of playfulness have been observed in our robot studies such as enjoyment, curiosity and active engagement [23], [28]. Children have said that they had fun using the robot, increased their sense of independence in play, and preferred to do things using the robot rather than directing another person [7]. These studies have shown the potential of robots to help children with motor impairments to engage in free play and show their playfulness, promoting cognitive and social development.

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