WORKING TOGETHER WITH ROBOTS TO IMPROVE LEARNING

TIMOTHY GIFFORD

Movia Robotics, Inc. 72 Prospect Pl
Bristol, CT 06010, USA
E-mail: tgifford@moviarobotics.com
www.moviarobotics.com

Collaborative robotics provides a unique opportunity for educating children. This intervention technique has raised concerns over the ethical implications of teaching children social skills with a mechanical device. Will the children prefer to interact with a robot and turn away from human interaction? Will robot-based therapies replace human therapists, taking the humanity out of the child's education? Providing successful training interventions to children with ASD is very challenging. Children with ASD have difficulty maintaining engagement and attention. They often do not like social interaction. Robot-Assisted Instruction (RAI) overcomes some of these challenges. Children find robots engaging and often treat them as a social entity. People can be overwhelming, presenting multiple social cues simultaneously. The robots are simpler than people which provides an opportunity to teach social skills one aspect at a time. The robot and associated devices act in concert with the facilitator enabling them to work as a team as they teach the child. In RAI, the robot leads the children through training interventions giving the children experience in activities related to social emotional learning, learning readiness, activities for daily living and academics. The robot provides an opportunity for the child to practice social interactions in a safe and predictable environment. The systems are semiautonomous giving the facilitator a powerful tool to provide educational instruction while maintaining control over the system to insure appropriate application. The system can dynamically change its role to meet the child's level of engagement and interaction. This combined with the participation of the facilitator both through control and adjustment of the system and directly with the child through prompting ensures that the intervention is safe and comfortable while being efficacious for the child. The robot and human facilitator team provide training experiences that improve the outcomes for children by providing a safe and comfortable practice environment. The skills acquired are generalized and used by the child in situations where the robot is not present.

- **Background**

- ***Autism Spectrum Disorder (ASD)***

ASD affects children in many different ways. Our approach pays particular attention to issues involving interactions across multiple modalities including interpersonal coordination through movement and gestures. Children with ASD who have imitation impairments at a young age also present with language delays in the preschool years (Stone & Yoder, 2001). Imitation deficits in young and older children with ASD correlate with their other social skills such as joint attention (i.e., ability to coordinate attention between people and objects) and their understanding of others' intentions (Mundy, Sigman, & Kasari, 1990; Baron-Cohen & Swettenham, 1997; Sigman & Ruskin, 1999; Charman et al., 2003). Imitation training, such as reciprocal imitation and visually cued imitation, improves the social communication skills of children with ASD (Ingersoll & Gergans, 2007; Ingersoll, Lewis, & Kroman, 2007; Ganz et al., 2008). Children with high functioning ASD showed fewer correct responses during gestures following imitation, gestures to command, and gestures during tool use (Mostofsky et al, 2006). Young and older children with low and high functioning ASD have impaired fine and gross motor coordination including basic motor skills such as locomotion and upper limb tasks as well as static and dynamic balance tasks (Ghaziuddin, et al., 1994; Henderson & Sugden, 1992).

- ***Motor Performance and Joint Attention***

Findings indicate that enhancing the motor performance of children with ASD may facilitate their poor social communication skills (Sutera et al., 2007; Brian et al., 2008; Gernsbacher et al., 2008). Joint attention (JA) is the ability to focus one's attention to that of a social partner (Mundy & Sigman, 2006). Children with ASD have deficits in appropriately responding to JA. Studies suggest that spontaneously initiating JA is significantly impaired in children with ASD. Four-year old children with ASD improved their response and initiation of joint attention behaviors following joint attention training (Whalen & Schreibman, 2003). Another study found that young children with ASD make significant gains in language development following JA based intervention as compared to an untrained control group (Kasari et al., 2008). Due to the JA and other skills deficits with children on the Autism spectrum and educator can have a very difficult time with the engagement of Autistic students in a typical classroom setting. These difficulties can be both academic and behavioral in nature. These difficulties are further enhanced by the anxiety a child with Autism can have being in a classroom because of the inability to handle the various situations and there needed responses that occur throughout the school day.

- ***Effects of Robot Interactions***

Research has shown that children with autism have a unique affinity towards robots. This is evidenced by their willingness to engage and interact with the robots socially. Several researchers have shown that children with ASD may demonstrate more engagement with robots than with humans (Robins, Daughtenhahn, & Dubowski, 2006); Bekele et al., 2013, and Kim et al., 2012). This has opened the opportunity to lead the children through productive learning activities. Further research confirmed the robustness of the engagement to robots seen in children with ASD (Toh, 2016). Beyond engagement there are many beneficial effects for the child when interacting with a robot. Multiple studies have shown an increase in compliance within participants after working with robots. (Bainbridge, 2008; Srinivasan et al., 2015). Research has also shown an increase cognitive learning gain (Leyzbeg, 2012). Also, children with ASD produce higher rates of joint attention that are comparable to typically developing children when interacting with robots (Kim et al., 2012; Pop et al.). Importantly there is evidence that these skills are generalized and present in the participants when the robots are not present. This was shown to be true for social skills where the children demonstrated generalization of social skills with people, including eye contact (Scassellati, 2018).

- ***Robot as Embodied Social Interactor***

Research demonstrates that children with ASD produce more vocalizations when engaging with robots than with other humans or a computer screen. This was shown in a study where students exhibited increased verbalization and socialization with an embodied robot versus a screen-based app and were more socially comfortable than with humans (Kim, 2013). Part of this effect might be due to the stimulation of mirror neurons when an embodied entity occupies the same space as the participant. (Gazzola, 2007). This increased brain activity leads to an increased engagement in motor skill activities and joint attention (Tapus, 2012). Robot based intervention can target joint attention behaviors during triadic interactions between the child, the tester or teacher, and the robot with the robot as the object of JA. Robot based interventions can be also used to facilitate complex motor coordination and postural control of children through imitation. Robots can be used to facilitate action imitation and interpersonal coordination. Research in embodied cognition shows that joint coordination activities improve interpersonal coordination (Marsh et al, 2009) Research using robots with children in joint movement activities shows gains in interpersonal coordination as well as spontaneous appropriate verbalizations (Srinivasan et al., 2015; Kaur et al, 2013).

- ***Benefit as Assistive Technology***

Robot Assisted Instruction systems provide the basis for a deployable assistive technology system for working with students with ASD in the school, clinic or home environment. The ability of the robot to lead the child through training interventions leaving the specialist free to direct and observe the interactions is beneficial to the child and the specialist. The child finds the interactions more enjoyable and accessible with the potential for more time on task. Having the robot lead the activities gives the therapist a better opportunity for observation and to collect data while dynamically assessing the progress of the child. The objective nature of the robot interaction also removes some of the variability of delivery. Children with ASD maintain good engagement with RAI over long periods of time. Skills learned with the robot are generalized and repeated by the child when the robot is not present.

- **Method**

- ***Robot, Child, and Facilitator Grouping***

The robot, child and facilitator form a synergistic group that interact with each other. The robot leads the child through educational activities including lessons and games. The facilitator interacts with the child and controls certain aspects of the robot's behavior through the controller. These 3 players interact as a group. The robot acts in a semi-autonomous way providing interactions in a linear fashion with dynamic modifications to delivery and complexity. The child interacts through speech, movements and by pressing graphical icons on a tablet. The tablet provides a way for the child to input responses that is unambiguous. It enables the robot to respond without the necessity for speech recognition. This is important as speech recognition software is prone to mistakes especially with children and those with speech impediments. The speech and movement interactions are interpreted by the facilitator and then input into the system. The robot makes the appropriate response based on the inputs from each source.

- ***Roles and Context in Defining Interactions***

The robot is perceived as an animate social entity by the child. The robot and child interact within the context of a social interaction. The context changes throughout the session but it always remains consistent to what is appropriate at that time. The robot will take on different roles based on the needs of the moment. Sometimes the robot is a teacher and sometimes it is a playmate. The robot has the ability to change between roles by changing its mode of operation. Each mode is a state of equilibrium where the robot can proceed along a reduced set of action possibilities. These action possibilities fully describe what is appropriate for the robot in each role. Since the robot has only a few action possibilities within a specific role it is possible for the semiautonomous control system of the robot to make appropriate action choices. The robot will act proactively, leading the child through the activities. If the child changes her behavior to something that is not within the context of the activity the robot can switch to another role or state of operation. This new role can be to try to return the child to desired state of participating in the lesson or the new role can follow the child to a new action state. This state meets the child at their current level. For example this new role could be one of playmate or of de-escalation. Here the robot will interact with the child proactively to bring the child to a more favorable state of learning readiness.

- ***Multimodal Interactions***

The interactions between the robot and child are multimodal in the form of speech, movement gestures, expressions and sounds. The tablet displays graphical representations of concepts that are being taught. The tablet also provides graphical buttons for the child to choose from when answering questions. These multiple forms of interaction provide many opportunities for engagement and rapport building between the child and robot. These coordinated activities also provide opportunities for shared experience between the child and facilitator. These experiences can be shard in the moment through joint attention bids and later as memories for storytelling and other pragmatic communication activities.

- ***Interaction Structure***

The interactions between the robot and child are structured to support specific types of engagements. The structure is maintained from session to session to give the child a predictable yet dynamic experience. This is important to provide a comfortable experience for the child while maintaining novelty. The robot engages the child through social interaction when first greeting the child. The robot greets the child by name and expresses how it is glad to be with the child and that they will get a chance to play together. The robot goes onto say that it likes to work and learn and play. These statements by the robot express that the robot expects them to have a positive experience.

The robot then asks the child to move with it in a imitation activity. The robot asks the child to copy what the robot is doing. The robot moves through a simple set of repetitive arm gestures to music. The child needs to attend to the dynamic movements of the robot's limbs. The child must attune to the rhythm and character of the robot's movements. This attention and movement by the child stimulates their nervous system. This stimulation in the service of copying the robot provides practice in interpersonal and intrapersonal coordination. These activities are very helpful for children with autism who often present with dyspraxia and coordination deficits.

The joint activity has been shown to improve the interpersonal synchrony between the robot and child and has been shown to generalize to interactions between the child and other people when the robot is not present. (Kasari et al., 2008). These joint activities support communication through embodied cognition.

The child is then led through skill building activities following Applied Behavioral Analysis (ABA) techniques. These lessons follow Discrete Trial Intervention structure with multiple opportunities for supportive prompting. The child is led through multiple activities, some are lessons and others are games that provide further engagement through fine motor interactions on the tablet. The session is ended with a transitional activity of leave taking. In this activity the robot transitions the child away from playing with the robot. The robot expresses that it enjoyed being with the child and looks forward to playing with the child again in the future.

- ***Facilitator Participation***

This system is an example of collaborative robotics where the robot and facilitator work together to bring the child through the training interventions. Robot provides a dynamic tool that can engage and lead the child through multiple activities while dynamically altering its behavior to help the child achieve a favorable learning readiness state. The facilitator is able to guide the system to provide nuanced interactions. The facilitator provides inputs about the behavior and state of the child, guiding the system and improving its effectiveness. The robot takes the attention of the child and enables the facilitator to focus on observing the progress of the child providing appropriate inputs to the system and taking assessment notes for program use.

- **Conclusion**

While using robots to work with children is counter intuitive. RAI provides an opportunity to positively impact the special needs community with a useful and effective assistive technology tool. The ability of the system to provide an experience that can emerge dynamically at the level of participation of the child under the supervision of a facilitator helps to ensure that the experience is safe and positive for the child. Concerns of the system misunderstanding the child or providing stressful interactions that could be harmful or a regressive from a skills acquisition standpoint are mitigated by the huma in the loop intervention and control strategy of the RAI system. Robots and people working together as a team offer the best results with each bringing their particular benefit.

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