

Research Paper

Inclusive Education for Young Children with Autism Spectrum Disorder: Use of Humanoid Robots and Virtual Agents to Alleviate Symptoms and Improve Skills, and A Pilot Study

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ABSTRACT

Individuals with autism spectrum disorder often struggle to establish and keep positive relationships with peers and adults due to experiencing communication and social difficulties. It has been shown that humanoid robots and virtual agents can enable interventionists to maximize engagement during instruction and program for generalization. Having employed the humanoid robots as a mediator and therapeutic support tool for children with autism spectrum disorder can help to support inclusive education for young children with autism spectrum disorder. Similarly, the findings obtained in many research studies that have been carried out recently support the use of technology-aided interventions and instruction with interactive virtual agents on children with autism spectrum disorder. Therefore, in this study, first, as a result of a scoping review, the use of humanoid robots and virtual agents for inclusive education is discussed. Then, the information about a pilot study based on single-subject research model is presented. The aim of the pilot study was to evaluate whether children with autism spectrum disorder could benefit from a humanoid robot in improving their symbolic play skills. Because as the related literature confirms a developmentally appropriate curriculum involving symbolic play is necessary for educational activities targeting young children. It was seen that throughout the sessions carried out in the pilot study, the children had high engagement with the humanoid robot and the parents' feedbacks showed that the children benefitted from the humanoid robot in improving their symbolic play skills. Finally, challenges, opportunities and future research directions in the related domains are provided in this paper.

**INTRODUCTION**

Inclusive education can be described as an attempt to educate all children in the same school, regardless of the students' background, attainment level or special educational needs. By this way, children with additional learning needs and special educational requirements are educated within an ordinary school, rather than a specialist school. However, adaptations are needed for physical spaces, school routines, classroom rules, and teaching styles in order to ensure that all students are able to access all resources (Loreman, Deppeler, & Harvey, 2005). Providing adapted timetables with different start and finish time and specialist equipments such as computers, communication devices, or voice recorders are examples for the adaptations. Being able to access quiet spaces, leave the classroom when overwhelmed, or have additional support from specialists or support from staff when needed are other examples for the adaptations. It has been shown that through inclusive education, higher achievement and improved skills can be achieved in students with additional needs (Hehir et al., 2016). Moreover, it has been shown that when education is truly inclusive, it can offer great benefits for all students, such as boosting friendships, improving communication, and encouraging more refined social skills for all the students. In addition, inclusive schools have generally fewer absences and referrals for disruptive behavior (Bakken, 2016).

Over the last decade, in the education of children with disabilities, there is a movement from special needs education towards inclusive education. This reflects a change from the medical model of disability as a result of focusing more on human rights in disability field (Hurst, 2018). As it was declared in the Salamanca Statement in 1994 (UNESCO, 1994) and reinforced by Article 24 of the Convention on the Rights of People with Disabilities in 2006 (United Nations Convention on the Rights of Persons with Disabilities, 2006) regardless of disability or special educational need, schools should accept all children. Inclusive education increases participation and reduces exclusion, and this way responds to the diverse needs of all learners. It aims to ensure the participation of all students in quality education and not only refers to people with disabilities but to including all marginalized and vulnerable groups. This approach requires some adaptations to the educational system so that the needs of individuals can be met without forcing them to fit the system (Oliva, 2016).

Autism spectrum disorder (ASD) is specified by having social, communication and behavioral challenges. Children with ASD are often being diagnosed at a young age, typically 1.5-6 years of age (Gabbay-Dizdar et al., 2021), and they are commonly being educated within inclusive settings. They often experience anxiety while having social interaction with other people. Anxiety leads

to difficulties for children with ASD in getting engaged in social interaction, and staying focused while collaboratively working with a peer or another person (White, Oswald, Ollendick, & Scahill, 2009). Therefore, children with ASD are often developmentally delayed in one or more areas. Because many skills are learnt by observing others or engaging with them. Although the inclusive education of young children with intellectual and/or physical disabilities such as ASD is highly desired and considered to be best course of action, most of early childhood educators do not feel themselves as prepared to deliver appropriate and effective instruction for children with various intellectual disabilities and they generally require support to successfully meet the children's unique needs (Brodzeller, Ottley, Jung, & Coogle, 2018). Early childhood educators should deliver interventions specifically designed and tailored to the children's learning needs and they should adapt the learning environment, materials, activities, instruction methods, and assistance provided so that each child is sufficiently and appropriately supported (Brodzeller, Ottley, Jung, & Coogle, 2018). They should also encourage the children to succeed as independently as possible.

Children with ASD often engage easily in predictable and consistent activities not involving social demands; therefore, they easily get engaged with using technology and from an early age they can use tablets and computers. They also love interacting with robots. Due to their predictable responses and ability of repeating things and behaving in a consistent way, they are perceived by children with ASD as less intimidating compared to humans and it is thought to have advantages in helping children with ASD to learn. In this paper, the use of humanoid robots and virtual agents within inclusive settings to address the diverse needs of young children with ASD is presented. The remainder of this paper is as follows. The second section provides information regarding inclusive education, its opportunities and its challenges. The third section presents information about methodology used in this study. Information about the use of robots and virtual agents and how they can be used within inclusive settings is given in the fourth section. The fifth section provides future research directions regarding the use of robots and virtual agents for inclusive education. Finally, the paper is concluded in the sixth section.

Inclusive Education - Opportunities versus Challenges

For being a leading way in providing all children a chance to be in a regular classroom setting in order to learn and develop their academic and social skills, inclusive education generates learning opportunities for children, otherwise who would be normally excluded from traditional educational system (Ainscow, Dyson, & Weiner, 2013). (Ainscow, Dyson, & Weiner, 2013). Furthermore, inclusive education appreciates the unique contributions of students from all backgrounds to create a chance for different groups to grow together. Nevertheless, its progress is slow due to the fact that it requires considerable changes to the existing school system and at all levels of society.

It has been shown that through inclusive education culture of belonging and respecting and offering learning opportunities about acceptance of individual differences is promoted (Berryman, Ford, Nevin, & SooHoo, 2015). In addition, all children get a chance of being involved in their community and this way they have a sense of belonging and better prepared for life. Although children have different abilities and varying degrees of motivation to learn, they can focus on their individual goals, at the same time they can collaborate with their classmates, develop their strengths and gifts and have opportunities in developing friendships (McCay & Keyes, 2001). Finally, the parents are encouraged to be involved in the education and school activities of their children.

Although inclusive education offers great opportunities as mentioned above, there are challenges in its implementation. It faces value variances, and conflicts can emerge in it due to integrating disadvantaged children from other races into the traditional school structure. In addition, due to the characteristics of inclusive education and user readiness-related factors, discords may emerge (Conner & Ferri, 2007). Moreover, people may perceive inclusive education as a dramatic change when it is introduced as an innovation, and parents and educators may hesitate to accept it (Haug, 2017).

It is known that significant educational reforms can lead to changes in the authority structure and cause an alteration in the role of relationships. Importantly, the quality of inclusive education can be harmed due to imbalances in the distribution of authority and responsibility (Suleymanov, 2015). Consequently, inclusive education can lead to varying degrees of issues in case of the disagreement of teachers and their assistants or special needs educators. Moreover, some individuals can resist inclusive education and cause practical barriers to it (Zwane & Malale, 2018), although it does not challenge their values. Their resistance is generally abstract and results from a psychological obstacle; therefore, professional treatment is needed. Practical barriers to inclusive education can demonstrate themselves in the form of system, time constraints, and resources (Andrews, Walton, & Osman, 2021). On the other hand, inclusive education makes it necessary to overcome resource barriers by involving teacher training, teaching materials, and curriculum adaptation (Miles, 2000). In addition, the bureaucratic nature of the existing educational system constitutes a structural barrier to inclusive education. Therefore, practical barriers can slow down and even harm innovation because the design of inclusive education requires significant amount of time in order to adapt to the existing educational system.

METHODOLOGY

In this study, first, a scoping review was carried out as a way of incorporating scientific evidence into the use of robots and virtual agents to alleviate the symptoms of children with ASD, to improve the various skills of these children and to engage these children better in inclusive education. The reason for preferring the scoping review model to a systematic review model was that a broader scope than a traditional systematic review with correspondingly more expansive inclusion criteria could be satisfied. As the literature given in this study proves that robots are promising tools to alleviate various symptoms of ASD and improve the academic and/or social skills of children with ASD and in some cases their benefits have the potential of addressing multiple ASD symptoms at the same time.

The scoping review was carried out using the Arksey and O'Malley (2005) framework. Several electronic databases including Web of Science, Scopus, PubMed, Medline, ERIC and Google Scholar, and the grey literature were explored to identify scoping review studies published from 1999 to December 2021. The reason for covering the grey literature in this study was that the grey literature consists of research and materials produced by organizations outside of the traditional academic publishing and distribution channels. Common publication types found in the grey literature include white papers, working papers, reports, evaluations and government documents. All the literature concerned with the use of robots and virtual agents for relieving the symptoms of ASD and improving the academic and/or social skills of the children with ASD was considered in this study. However, the articles without novel content were eliminated to provide consistency and eliminate redundancy in the results.

After completing the scoping review, a single-subject research design-based pilot study that involves two children with ASD and a humanoid robot was carried out. The first reason for using a mixed research model was to support the findings of the literature review with the pilot study. The second one was due to the funding related unavailability of virtual agents to perform the associated pilot study. As explained in (Horner et al., 2005), although single-subject research designs may involve only one participant, they typically include multiple participants, likewise this study. Each participant serves as his/her own control. For each participant, during and/or after intervention, performance is compared to performance prior to the intervention. Single-subject research designs employ one or more dependent variables that are defined and measured, as well as one or more independent variables (Horner et al., 2005). The pilot study was conducted to determine whether working with a humanoid robot could help children with ASD improve their symbolic play skills and increase their engagement in various learning tasks. The reason for focusing on symbolic play skills was that children with ASD typically have significantly greater difficulties in symbolic play than typically developing children and children with other neurodevelopmental disorders (González-Sala et al., 2021). Symbolic play is a powerful vehicle for supporting emotional development and communication and embraces all developmental capacities (Weider, 2017). The difficulties of children with ASD in symbolic play skills are greater in situations of spontaneous or free play and the absence of symbolic play skills or deficiency in them can be seen as an early indicator of ASD (González-Sala et al., 2021).

The pilot study was comprised of teaching, follow-up and generalization sessions. One girl and one boy aged 6-8 years who were diagnosed with ASD were included. A data collection form was designed to collect the participants' responses. In the targeted game, the dependent variable was the acquisition level of the skill steps by the participant children. At the stage of determining the dependent variable of the pilot study, first, negotiations were held with the families and the teachers in order to get information about the children. Then, the children were observed in their educational settings, too. Thus, it was determined what the participant children could do and what skills they needed to develop themselves. The independent variable of the pilot study was the teaching practice presented by the humanoid robot by using the least-to-most prompting (LMP) procedure.

Robots and Virtual Agents

It has been shown that children with ASD generally enjoy working with robots and engage with them better than humans; therefore, robots can be used to support the needs and unique abilities of children with ASD in school settings (SoftBank Robotics & ERM, 2021). However, better engagement is not the only benefit that robots can offer to children with ASD, as listed in the following.

- When interacting with robots, children with ASD can improve their cognitive learning skills (Robins, Dautenhahn, & Dickerson, 2012).
- While interacting with robots, children with ASD can produce almost the same rates of joint attention with their typically developing peers (Kumazaki et al., 2018).
- Robot-based interventions can be used to improve postural control and complex motor coordination of children with ASD (Robins, Dautenhahn, & Dickerson, 2012).
- Robots are useful tools to foster action imitation skills of children with ASD (Rakhymbayeva, Amirova, & Sandygulova, 2021).
- Robot-based interventions through joint movement and joint coordination activities can improve interpersonal coordination and spontaneous appropriate verbalizations of children with ASD (Boccanfuso et al., 2017). It has been demonstrated that children with ASD exhibit increased socialization and produce more vocalizations if they engage with robots than with computers/tablets/smart phones or other humans.
- After interacting with robots, children with ASD better generalize their social skills including eye contact (Shamsuddin et al., 2012).
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As well as individual benefits, using robots may lead to an increase in compliance within participants. In addition to their benefits to children with ASD, robots offer benefits to therapists and educators. Robots can lead children with ASD during interventions and by this way they leave the therapists and the educators free to direct and observe the interactions. As a result, the therapists and the educators are able to collect data and continuously assess the children's progress. Humanoid robots, one of them is shown in Figure 1 ("NAO the humanoid and programmable robot", 2021), are the best option for such goals.



Figure 1. NAO (Courtesy of Softbank Robotics)

Desideri *et al.* (2017) carried out a study funded by a European Union project “EDUROB” (EDUROB 2013). In this project, researchers from Bulgaria, Italy, Lithuania, Poland, the UK and Turkey tried to explore whether cognitive development can be enriched via mediated learning using humanoid robots or not. The researchers proposed an intervention model aiming to drive students’ cognitive processes by using the advantages provided by humanoid robots. The Italian partners of the project explored whether a humanoid robot can be effectively used to improve educational interventions targeting children with ASD or not. Preliminary results of the study proved that interaction of children with ASD with a humanoid robot called NAO might increase engagement and ease goal achievement in educational activities (Desideri *et al.*, 2017).

Karakosta *et al.* (2019) examined the effects of play sessions carried out with a humanoid robot called Kaspar on the social and communication skills of children with ASD. The research covered a total of 111 individual sessions performed in 10 weeks and was conducted in a Greek school. It showed that Kaspar positively influenced the behaviors of some of the participants in some domains including communication and interaction, focus, unprompted imitation, and prompted speech. Moreover, the teachers offered to use Kaspar in daily teaching tasks during regular classroom activities.

Virtual reality environment is safer for individuals with Pervasive Developmental Disorder (PDD). Since deficits in joint attention skills affect social relationships of children with PDD, Cheng and Huang (2012) proposed the use of data glove to practice joint attention skills in virtual reality environment and designed a Joint Attention Skills Learning (JASL) system with data glove tool. The JASL system has been particularly designed to focus on the skills of pointing, showing, sharing things and behavior interaction. It is designed in playroom-scene and presented in the first-person perspectives for users. Cheng and Huang realized an experimental study using the JASL system based on a single subject multiple-probe design in 3 months. The results show that the JASL system have positive effects on improving joint attention skills. With a similar effort, Ravindran *et al.* (2019) assessed the feasibility of using Floreo's Joint Attention Module in children with ASD. Over 5 weeks, a total of 12 children with ASD received training with Floreo's Joint Attention Module for 14 sessions. It showed that using Floreo's Joint Attention Module led to considerable improvements in core joint attention skills.

Charlton *et al.* (2020) conducted a research to prove the effectiveness of avatar-delivered instruction on social initiations by children with ASD and found that children with ASD love learning with the help of virtual characters. In their research, the authors used an animated fish avatar shown in Figure 2 and found that children with ASD learned more by talking to Marla than they learned by talking to another person. It was shown in their research that animated avatars could be used to teach behavioral skills to children with ASD. The live part of the animation relies on software that moves the animated avatar as researchers have real-time conversations and lessons with participants (Charlton *et al.*, 2020). The participants were sitting in front of a screen with the live-animated avatar, while researchers were controlling the live-animated avatar with the software in a separate room in which they could view the participants through a two-way mirror and respond by speaking into a microphone (Avatar adventures 2021). It is known that children with ASD are not able to start a conversation easily. With the goal of addressing this problem by using live-animated avatars, Charlton *et al.* (2020) first allowed the participants to practice the five steps of how to start a conversation, i.e., looking at the person and smiling, standing about an arm’s length away, asking a question, using a nice voice and waiting for a response, with the live-animated avatar. Then the authors brought in same-aged peers and relatives to make the concepts more concrete. The results showed that the participants had high levels of engagement with the live-animated avatar, learned how to start a conversation with the individuals around them, and generalized the skills (Avatar adventures 2021).



Figure 2. MARLEY (Courtesy of INVIRTUA)

Preliminary Information and Pilot Study

Robots are promising tools to support children with ASD and other neurodevelopmental disorders in their education and help to develop their social skills. Educational robots are specifically designed to interact with children during educational activities and they can be part of an extracurricular activity or an existing school curriculum. Although no clear evidence supports that robots are effective tools to treat children with ASD, it has been shown that they can be used to support the children's learning process (Zhang et al., 2019). However, robots used for children with ASD are different from robots used by students with ASD. For instance, robots used for children with ASD are useful in improving the level of attention of the children similar to any other technological device. However, robots used by children with ASD are useful in teaching subjects through a set of activities centered on computational thinking so that active learning is promoted (SoftBank Robotics & ERM, 2021). Depending on learning objectives, robots can be used in different roles including learning material, learning support tool, peer, assistant, teacher, and remote presence (Chang et al., 2010; Diyas et al., 2016; Mubin et al., 2013; Tanaka & Kimura, 2009; Tazhigaliyeva et al., 2016). In these roles, robots can be used for oral reading, storytelling, and question-answer scenarios. They can also be used to receive instructions from children or ask children to perform selected tasks. Finally, in competitive games, robots can also be used to play the role of a coach or a fair judge. It has been shown that interesting and engaging nature of robotics activities lead students to share feelings and ideas and gamification of this process promotes positive teacher-student interactions (Kucuk & Sisman, 2017).

Feng et al. (2018) demonstrated that typically developing children's preference for a set of cartoon images and human images decreases sharply when eye size is enlarged and realism of face images is increased, but these effects are not present among children with ASD. Their findings demonstrate the existence of the uncanny valley effect in typically developing children. Uncanny valley refers to people's response to a human-like artefact that abruptly changes from high affinity to revulsion when the artefact approaches but fails to have an actual human appearance (Mori, 1970). However, it is not present in children with ASD because of their reduced sensitivity to minor changes of face features and their limited visual experience to faces in consequence of diminished social motivation (Feng et al., 2018). Therefore, humanoid robots should be designed by focusing on the efficacy of intervention, instead of focusing on the uncanny valley effect.

It was shown that children with ASD showed less interest in some specific types of toys than their typically developing peers, but their overall rates of functional or symbolic play behaviors were not different from their typically developing peers (Dominguez et al., 2006). However, Warreyn et al. (2005) found that children with ASD engaged in symbolic play and were able to imitate symbolic play acts, similar to their typically developing peers. Similarly, Naber et al. (2008) reported that there were no differences in length of play time or time spent in symbolic, functional, or manipulative play between children with ASD and typically developing children. With a similar research goal, Thiemann-Bourque, Brady, and Fleming (2012) conducted a study to find out whether children with ASD have deficient play skills or not. The results obtained by the authors showed that there were no significant differences between children with ASD and their typically developing peers in their play, but the children with ASD engaged in more conventional play compared to the typically developing children.

It is known that for young children, a developmentally appropriate curriculum involving symbolic play as a key component is a must for a successful program (Reed, 2007). Because symbolic play skills are essential for the development of a child (Petrović-Sočo, 2014). Therefore, at a special education school in Edirne, a research study was carried out to determine whether children with ASD could benefit from a humanoid robot in improving their skills in the target game, as shown in Figure 3. Ethics committee approval was received for this section from Trakya University, Trakya University Social and Human Sciences Research Ethics Committee. Written consent was obtained from the participants' parents.

As mentioned in the methodology section, the research study was based on the single-subject research model and one girl and one boy aged 6-8 years who were diagnosed with ASD participated in the study. In order to eliminate any potential risks, the scenarios had been created and tested with the simulated NAO using Choregraphe software ("NAO Software 1.14.5 documentation", 2021), as shown in Figure 4. Then, the scenarios were deployed to the real NAO and the interventions were realized. The NAO presented the skill steps of the game to the children using a hierarchy of prompts from the most moderate prompt to the least moderate prompt level. During the process, the independent variable was applied two days a week. For each of the children, two teaching sessions consisting were held on each day designated for teaching the target behavior and five trials were conducted in each of the teaching sessions.



Figure 3. Interventions using the NAO

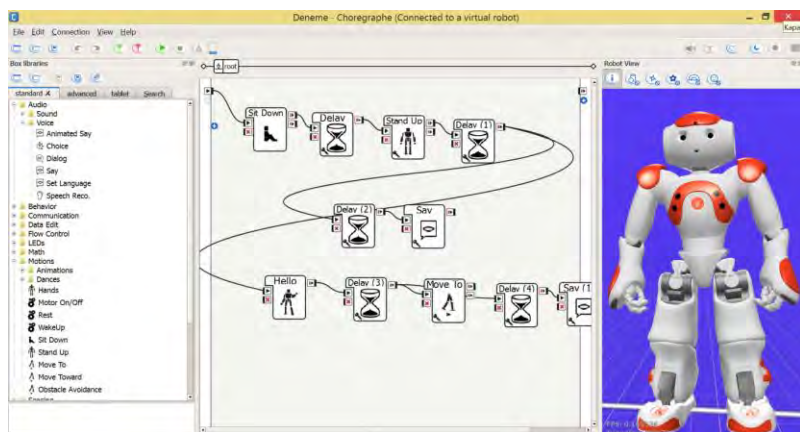


Figure 4. Creating and testing the proposed scenario using Choregraphe software

The acquisition level of the participant children for the dependent variable was determined as 100% correct fulfillment in all skill steps of the game without getting any prompt. Also, his/her participation and cooperation in the study were reinforced verbally at the end of each session. Different from the others, the generalization sessions were conducted by the teachers of the participant children. The NAO was not used in the generalization sessions. Throughout the sessions, the children had high engagement with the NAO and benefitted from the NAO in improving their symbolic play skills. The parents' feedbacks confirmed this, too. The importance of the results obtained in this study lies in the fact that the development of symbolic play and its effects on the holistic development of children at an early age can have significant pedagogical implications on educational practice if teachers are directed to carefully watch, listen to, document and reflect on children's symbolic play (Petrović-Sočo, 2014). This way the teachers can understand symbolic play better and comprehend it through the child's perspective and then apply appropriate methodological procedures for its encouragement and promotion (Petrović-Sočo, 2014). Since the results are promising, the study will be realized with more participants after receiving the approvals and consents.

Future Research Directions

Robots can also be used as social mediators and this role can be investigated in terms of encouraging interaction between children with ASD and their peers or other people (Yaman & Şişman, 2019). Independent variables that may have effect on the level of interaction can be eliminated by carrying out the study in an environment where children and robot(s) are alone (Yaman & Şişman, 2019).

As the related literature shows, avatars are one of the novel tools to reduce anxiety and can be quite helpful to children with ASD. Avatars can let children with ASD ease into their sessions with less stress and this way lead them to more efficient learning. Different from traditional intervention options, avatar-based therapy is a viable choice that can be delivered with online learning in home-based settings. Avatars can perfect the experiences that benefit children having trouble interacting with adults in typical settings. Avatar-based therapy can be implemented at regular intervals via online meeting platforms and the sessions can be recorded to analyze the child's improvement.

Moon *et al.* (2020) performed a study to demonstrate the effects of therapeutic intervention with smart phone applications for individuals with ASD. As the results show, using smart phone applications is promising for therapeutic intervention for individuals with ASD. Nevertheless, more large-scale and well-designed studies centered on improving behavioral symptoms of ASD are needed (Moon *et al.*, 2020).

Using computer- and robot-assisted therapies has been demonstrated to provide benefits for social and intellectual functioning of children with ASD. Although these interventions are considerably promising, more research with a large number of participants should be carried out (DiPietro, Kelemen, Liang, & Sik-Lanyi, 2019). In addition, Alcorn *et al.* (2019) highlighted that there is no one-size-fits all design solution for robotics in autism education, and those current solutions may result in later challenges for children with ASD. Therefore, as stated by Serholt *et al.* (2017), there is a need to involve core stakeholders, the ones that have direct influence or may be directly influenced, in the design and implementation process and the overall process must be designed with educators, parents and the children to prioritize the needs and values of the users (Alcorn *et al.*, 2019).

CONCLUSION

After having been seen as an engaging toy for children with ASD, in recent years, with their distinct features humanoid robots have become promising tools for various types of interventions. It has been shown that humanoid robots proposed and designed for this purpose can help children with ASD learn cognitive, communication, social and emotional skills. As well as humanoid robots, virtual agents have started to be a novel solution for interventions in the last couple of years. Humanoid robots and virtual agents provide a high level of simplicity, repeatability, predictability and consistency to promote the engagement of children with ASD and let children with ASD practice new skills. Since they are not as dynamic and complex as humans to interact with, children with ASD can use them to learn and generalize new skills.

Given the responses from the participants of this study and the feedbacks from the parents regarding the acceptability and benefits of using the NAO in intervention, further research is needed to determine the roles that humanoid robots and virtual agents can serve in education to enhance outcomes of inclusive education for children with ASD. In parallel with this, there is also a need for an extensive study for maintenance and generalization of skills, fading of provided prompts, transitioning between different roles, and promoting functional independence.

Ethics and Consent: Ethics committee approval was received for the pilot study section of this study from Trakya University, Trakya University Social and Human Sciences Research Ethics Committee. The approval letter's number is 2019.02.10 and its date is 20.02.2019. Written consent was obtained from the participants.

Conflicts of Interest and Authorship: No conflicts of interest and authorship to declare.

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