



Humanoid Robot as a Teacher's Assistant: Helping Children with Autism to Learn Social and Academic Skills

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Abstract

Autism Spectrum Disorder (ASD) is becoming a growing concern worldwide. Parents are often not aware of the different nature of children with ASD and attempt to treat him/her the same way as other children. However, that causes more and more isolation of such children from the social interactions around them, resulting in more secluded and people-phobic behaviors. Nevertheless, similar to other children, children with ASD also like to play with toys. This observation has led to the use of toys in a way that mere playful activities could become sources of learning and skill-building, somewhat serving or assisting in the role of a human teacher. Robots have been observed to be fascinating for all children and compensating for a human companion to a certain extent. In this paper, a short study has been presented involving a humanoid robot programmed for a number of teaching and therapeutic behaviors, such as exercises, singing, explaining, and playing with children. Tests were performed on a small group of 15 children with ASD (ages 7–11) using these activities at a local school for children with special needs for a number of weeks. The objective of the study was to quantify the improvement in a number of behavior and learning parameters when children performed the activities with NAO robot present with the teacher, as opposed to the same type of activities performed by the teacher alone. The performance improvement was quantified in terms of the NAO robot activity as independent variable, and following dependent behavioral variables observed from the responses of children: (a) number of trials, (b) activity response time, (c) response type, and (d) behavior retention. Quantified findings from these tests are reported in this paper against average performance values (based on teachers and psychologists' evaluation). The results of the study have been found to be very encouraging which demonstrates the capability of robotic toys to improve the learning process for children with ASD. The results of this study also encourage the low-cost development and usage of such robotic toy systems for teaching and therapeutic applications that help such children to become better members of society.

Keywords Autism Spectrum disorder (ASD) · Human robot Interface (HRI) · NAO robot · Interactive games · Robot-based games

1 Introduction

Autism Spectrum Disorders (ASD) are usually defined as neurodevelopmental disorders in which a person has abnormal social interaction, impaired communication, language difficulties and lack imitational coordination [1]. ASD manifests in diverse actions, behaviors, and appearances, making each individual child a unique experience.

However, certain collective trades occur commonly in a larger number of children. These trades usually include behavioral abnormalities in terms of social interaction, delivery speech impediments, recognition difficulties, and expression inability. Hence, simple tasks that are essential for learning, such as following instructions, focusing on an activity, and attention spans, are extremely challenging for children with ASD, resulting in learning difficulties.

The conventional therapeutic methods include pictorial tools, e.g. cards, flip charts, posters, etc. The research community has also been active in using a variety of different electronic tools and toys, e.g., tablet PCs, mobile phone apps, and computer games, etc. The underlying objectives of the studies conducted using these tools is to improve focus, hand-eye coordination and memory retention in children with ASD. During past 5 years, several articles have been published to report experimentation with toys with smarter interfaces and robots. Compared to gaming applications in PCs, robots are

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more real and human-like and are expected to be more motivating for children with ASD. Robots act as companions for these children in that the robots can be touched and played with, as well as engaging in conversation. Therefore, a robotic toy system can be a very useful toy for getting children, especially those with ASD, involved in various types of activities and learning experiences. Objectively planned activities with such robots can lead to enhancements in behavioral outlook, improvement in learning and social interactions due to the better understanding of what is being taught, better hand-eye coordination, and longer attention spans. Above all, the human-phobic barriers can be removed when robots are being used since the ambiance of such activities make the children more involved into a gaming activity rather than a learning academic activity. Since ASD related behavioral problems are unique to each child, each robot used in helping these children also differs and is subjective to the unique requirements of that child. It is difficult to generalize or interpret a specific robot as the best solution in terms of improvements in children with ASD. Usually, group behaviors are the focus when designing such robotic systems such that a larger number of children could benefit from a smaller set of activities. The shape, size, and aesthetics of the robot, as well as its ability to interact with the child, make significant differences in the therapeutic process. Humanoid robots, being similar to humans, have shown better results than other robots [2]. Autistic children appeared to be more comfortable interacting with robots than humans [3]. Behavioral tests per initiation showed more improved results than that of human-only interactions for such skill-building activities.

A number of different technologies are currently being used to help autistic children become more independent and useful members of society. Most of these technologies fall into one of the following technological groups [4]:

- Virtual reality applications or environments, including technologies that create the environment, such as a cave;
- Dedicated applications or interactive environments, including tablets, computers and mobile phones;
- Telehealth systems or telerehabilitation systems;
- Robots.

Robots used in the therapy or teaching of children with ASD make considerable differences in four different areas of therapy, including social learning, verbal and gestural communication, imitation skills, and social interaction. Bartolome et al. [5] showed different therapies devised using robots in various parts of the world and their impact. It is also necessary to see the ethical compliances and compatibilities with robots. Hence, Coeckelbergh et al. [6] showed that robots are ethically accepted specialty robots that are implemented with human instructor supervision. Standard safety compliances with specific standards are also needed to be part of such compliance.

Cabibihan et al. [7] presented many different robots that are being used to help autistic children. This study is a brief survey of robot roles and their benefits. Several robotic platforms are listed, such as CHARLIE, FACE, Infanoid, IROMEC, KASPER, Keepon, Kismet, and NAO.

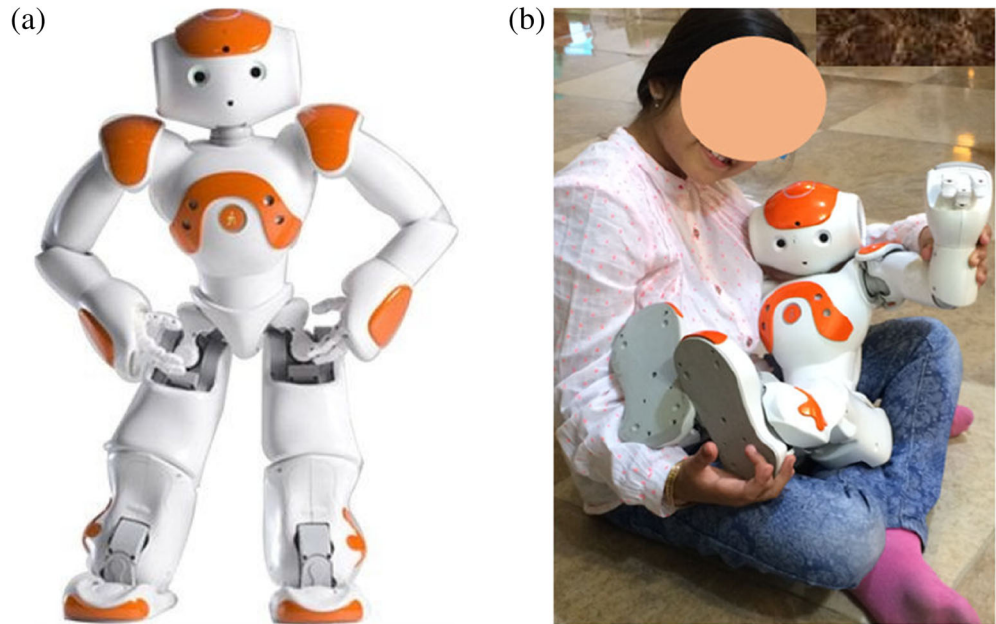
The Keepon robot is popular as a tutor [8]. The shape of the 25 cm tall robot is like a snowman with no hands and feet. It has 4 degrees of freedom which allows it to roll, bob, pan, and tilt. Yujin Robotics presented a robot named IROBI in the early 2000s. An experiment with IROBI shows that it is able to improve the concentration on the activities which involves learning compared with other technologies a web-based application or audio materials [9].

Many newer robots have also surfaced in the market, such as Popchilla, Zeno, Lucy [10], Rubi, Romibo and Robosapiens. These robots are mostly designed as humanoids or animal-shaped robots since both types have different effects on autistic children. Different results and improvements can be clearly seen [11] between a cat robot and a humanoid robot, Zeno [12]. KASPAR [13] and Tito [14] have been developed to express emotional faces like a human but they are able to make simplified faces [15]. On the other hand, FACE [16] and Zeno [12] are able to create more realistic human facial expressions. LeapFrog Schoolhouse™ [17], is a renowned toy company developed a toy named ‘LeapPad Learning Toy’ to improve the literacy skills of preschool or first-grade students. In a school environment, the company tested the toy on the students with an intellectual disability at different age groups. The study showed that the LeapPad learning toy helps the students with intellectual disability to enhance their reading skill by 29%.

The focus of this paper is on the humanoid robots. For research purpose, the NAO robot is one of the most popular humanoid robot in recent years. It is regarded as an endearing, personalizable and interactive robot companion [18]. NAO is half a meter tall humanoid robot that resembles a little human and mimics human-like movements in a very reliable manner. Figure 1 shows the robot and one activity in which a child is playing gesture display with the robot. Perhaps the only shortcoming in NAO is the cost since it is expensive compared to other types of robots.

For medical treatments, NAO Robot has been widely used. There are some other robots which are used in rehabilitation therapy [19]. The repetitive and predictable behaviors help to train children with Autism Spectrum Disorder (ASD) on how to perceive human and understand human emotions. Therefore, an autistic child easily becomes friend with NAO robot. Moreover, children having ASD show more interest in inanimate objects [20]. Few researchers are editing the software platform of NAO to improve the interaction between children with ASD and the robot NAO. For example, the system package in [21, 22] added an external camera along with the robot’s own visual system. This system leads to

Fig. 1 **a** NAO and **(b)** NAO being used in a gesture activity



improve the therapy with the children having ASD which is based on Human-Robot Interaction (HRI).

In [12, 23–25], it is shown how NAO is being used to develop a Lego therapy session for autistic children and their families. Using NAO in Lego therapy showed that long-term training does not exhaust autistic children, and they can easily follow and improve their skills. Specifically, in [3], it is clearly shown that using NAO in Lego therapy, which implements a single behavior, have shown better interaction results for an autistic child with his or her family and provides positive responses to surroundings. Several previous and current studies performed locally by our groups have improved confidence in using robotic toys for training and teaching purposes with accelerated results [26–29].

With commercial hype from the vendors of such robots, the user usually perceive these solutions to be very useful and performing in an incredibly remarkable level of enhancements in behavioral outlooks of children. However, to the best of our knowledge, the commercial literature fails short of providing concrete quantitative proofs of the improvement. Recently, [30–36], many researchers have attempted to provide a better quantitative comparison of their findings. However, each work in this list has provided more or less similar analyses, i.e., using attention span, and activity retention as main rubrics.

Similar to [30–36], we have developed a different analysis approach. However, we have made our activities more encompassing and broader coverage of general learning traits. Based on the methodology of activities (presented in the next section), teachers and psychologists were consulted with full study plan and their inputs were collected for how to quantify the subjective observations. Section VII elaborates further on the final converged list

of the variables used as rubrics in order to quantify the findings of each experiment. In addition, statistical significance of the overall activity is calculated using the T-test method. To the best of our knowledge, the above rubrics as well as the *p*-values obtained from the T-tests, provide a different quantitative treatment to the issue of using robotic toys with children with ASD.

2 Methodology

In the context of using robots for teaching children with ASD social and academic skills, we have started using the NAO robot (Fig. 1) with respect to certain specific functional activities. After programming the robot with the fundamental behaviors, various local institutions dealing with children with ASD were contacted, and the capabilities of the robot were presented to their teachers and psychologists. These presentations and subsequent discussions resulted in the following activity recommendations:

1. Robots can act as one of the children in the class and perform what the teacher asks the class to do. In this way, the robot will become a peer role model.
2. Robots can assist in performing physical gestures/exercises by performing them separately first and then performing the gestures with the children.
3. Pattern/color recognition using the robot.
4. Verbal communications related to social greetings and responses.
5. Mimicking and copying actions from/by the robot.
6. Songs and poems were sung by the robot that children could follow.

7. Playing interactive games involving physical exercises.

In light of the above recommendations, a research methodology has been formulated based on the following set of objectives:

1. To utilize the NAO humanoid robot for specifically designed activities related to attention span, social behavior and speech improvement.
2. To design the following sub-activities during this study:
 - a) Following instructions
 - b) Mimicking activities
 - c) Speech recognition
3. Identify and recruit appropriate groups of children by psychologists with the consent of their parents for the study.
4. Conduct the study strictly within the classrooms during the allocated time slots by the teachers.
5. Formulate specific quantitative measurements to quantify improvements in student behavior and learning.

Based on the above recommendations, several activities/games were designed using the NAO robot. The development of several of these activities/games are briefly described in the following sections.

2.1 Behavior Programming

The behaviors to be programmed were first discussed with the school teachers or related caregivers and were based on the targeted activity that was essentially based on the specific improvement in the learning skill-set of a selected child or group of children. These behaviors were first mapped into robotic movements as the skeletal framework of the behavior manifestation. In addition, the audio layer was super-imposed to add specific sound and language effects as well as light flashes on the robot body to give a more attractive and realistic outlook to the overall behavior. The skeletal movements were programmed using the key-frame animation concepts in the software environment *Coregraphe™*. Figure 2 shows the keyframes 58 to 65 at three locations where specific movements were produced using the mechanical movements. The software mapped the missing frames to produce smooth movements, in this case, the clapping gesture.

Once, all the basic behaviors were programmed, higher lever behaviors were constructed using combinations of the basic behaviors. For example, saying a greeting phrase and hand-shaking gestures can be programmed by combining several arm movement behaviors with greeting's audio layer superimposed within the same period.

Hence, following activities were programmed and used in the study:

3 Speech Related Activities (Song [SG])

Speech related activities involve understanding the spoken sentences and acting in accordance with what has been said. To accomplish an autonomous speech session, the memory requirements were large and posed the primary constraint with NAO's platform. In addition, language support available for the local language was not appropriately available from the vendors. This problem was addressed by making the audio component a "live" session in which the robot is actually conveying the speech phrases from another teacher sitting in the next room. The audio stream from this teacher is modified to sound similar to the robot talking in its natural tone. In this set of activities, the robot played interactive or play-along songs to the children and performed several physical movements corresponding to the statements in the song. Once the song is completed, the robot used positive reinforcement statements such as "hurray" or "well-done" with high-five gestures to encourage the children to complete more activities. For an unsatisfactory child response, the robot encouraged them through such statements as "let's play again" or "try again" with spread-hand and welcoming gestures. Figure 3 shows these activities.

4 Social Activity 1 (Story [ST])

In this social activity, NAO helped children with functions related to cultural practices that help students understand certain aspects of the culture that they live in. For instance, practices included greeting others, responding to a greeting, and answering questions. Understanding social practices is an ideal starting point for children with ASD, as this is where they are behind in their immediate surroundings. This process was packaged into a storytelling session in which a teacher used the live-audio stream feature with the robot and, through the application program of the robot, selected several behaviors remotely as needed. This application program was later modified into a mobile app so a teacher could select behaviors simply by touching the options buttons on the screen. The robot provided encouraging feedback to the child; if he/she responded correctly to the interactive parts of the story through statements, such as "well done." If the child did not respond correctly, the robot encouraged the student to try again and later use one of the following strategies to help him/her learn how to properly greet another person:

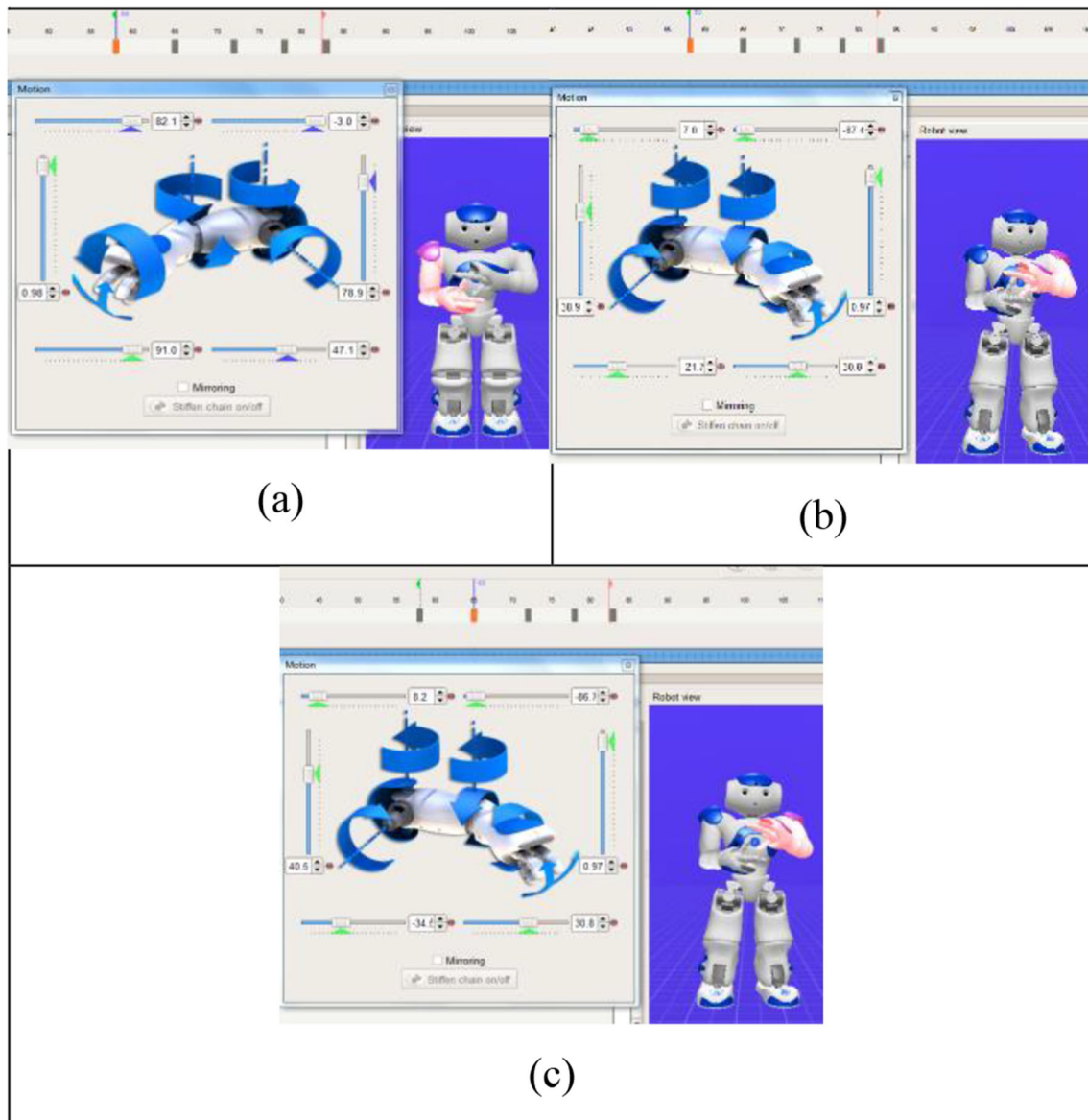


Fig. 2 Three keyframes in a sequence of clapping behaviors. Corresponding motor positions are changed manually to implant the keyframes

- Repeat the robot activity with the child or
- Direct the same activity to a teacher or a student that completed this activity successfully to provide the other student with a model to follow.

5 Social Activity 2 (Game [SS])

A social activity related to bidirectional communication was programmed in the form of the game commonly known as Simon Says. In this activity, the robot turned on its various lights (eyes, middle light, and headlights) and the child was asked to touch the organ related to it. For example, when the left eye lights up, the child touched

the left hand. The correct action would light up the robot with positive reinforcement gestures. Wrong actions were prompted by encouraging audible messages to make the student try again.

6 Mimicking Activity (Morning Exercises [ME])

In this activity, the robot performed several physical movements similar to exercises/work-outs, and the students were prompted to follow the robot by mimicking and repeating the same steps. The workout steps were also advised by the teachers/therapists and in light of the convenience and capabilities of the children in the study



Fig. 3 Activities with the NAO robot; **a** Simon Says game (SS), **b** story activity (ST), **c** morning exercises (ME), and **d** song activity (SG)

group. Several of the typical exercise routines included the push-ups, arm stretches, and horse-stance.

7 Testing and Results

Several visits were scheduled, typically once a week, to a local institution where the teachers selected a group of students. The selection was made based on teacher assessments that focused on selecting students who would benefit the most from planned exercises. To test and analyze the impact of the NAO robot, four parameters were formulated, and related measurements were made during each session for each child. These four parameters constituted four *dependent variables* in this study. The only *independent variable* for all activities was the NAO robot itself. The following is the account of how each dependent

variable was measured [all measurements were between 0 and 10 with 10 being the best or excellent outcome]:

1. Memory (MEM): how well the child remembers the game during the sessions. The teacher assigns the score out of 10 according to the subjective assessment.
2. Response Type (TPR): how well the child responds to the game. The higher the score out of 10 is, the higher the understanding of the activity is, and the more natural the response is.
3. Response Time (TMR): how quickly the child responds to the requirements of the game.
4. Number of Trials (NTR): the number of trials needed for a child to respond to the game in the same session.

Appropriate parental consents were obtained before registering the children for the study. The sessions were video recorded

in order to analyze all types of reactions and behaviors of the children. Behaviors programmed on NAO were tested mainly in a group of 6–10 children and each child had a different level of functionality or GSM-5 score; children had their own characteristics and behaviors that were known to the teachers and psychologist beforehand. Testing started with the following four programmed behaviors: morning exercises (ME), the Simon Says game (SS), a song activity (SG) and a story activity (ST). As expected, the outcomes from the first session were not very good, since children with ASD usually are not familiarized with new things easily. It was noted that most of the children were attracted by NAO and started to touch its different body parts to discover it and, subsequently, started to play with the robot as well. After the first session and after analyzing the different reactions of the children for the four different behaviors, we met with the teachers to collect more information regarding their students and to ask about the suitable types of activities that NAO could do with the children. The robotic behaviors were fine-tuned based on their feedback, and another round of tests was conducted with the children in subsequent days. This cycle was repeated for a number of sessions. There were remarkable improvements in the four dependent variables evaluated in each session, as described in Fig. 4. Each child had his/her own scores from six repetitions of activities, from which an average was calculated for that activity. The graphs in Fig. 4 show the average scores for each activity with respect to the four dependent variables.

For the Simon Says game, there is a significant improvement in the average scores for the response time variable during the sessions. The average score for the type of response variable increased during the first 4 sessions but decreased slightly for the last two sessions. The average memory variable score also increased during the first three sessions subsequently dropped and remained constant for the remaining three sessions. The average score for the number of trials was relatively constant for the first three sessions and subsequently decreased and remained constant for the following three sessions. It can be clearly observed that games similar to Simon Says can be used as a tool to help improve coordination skills and teach children how to listen carefully to and follow instructions. This game was very attractive for the children because it includes touching the robot sensors based on optical and audible instructions and, consequently, observing the response from the robot. It was also noted that higher functioning children were more interactive with this game. Children with lower GSM scores also showed improved retention by reduced number of trials for attempting the same exercise.

In the morning exercise behavior, the average scores for response type and time increased in a significant manner during the first 4 sessions. The average score for response type dropped during session 5 and remained constant in session 6, while the average score for response time decreased during the last two sessions from 3 out of 10 to nearly 2.3 out of 10. The average

score for memory was relatively constant for the sessions, except for session number 4 where it increased slightly from 1.25 to 1.5. The maximum number of the average score for the number of trials was 1, indicating that children with ASD react quickly to this type of behavior, mimicking physical activities with fun. However, the morning exercise was observed to be less attractive to children than the Simon Says game because it did not include any songs or touching NAO; however, good feedback was received from the children and they still liked it and were ready to do the exercise routines as soon as they were instructed to do so.

The story program was tested in the first session with all of the children, but it was observed that not all of them were interested in the activity, except for a few who liked the story very much. Those who were interested listened to the story carefully and answered questions asked by the robot when the story reached a specific scene. The questions were related to cultural responses, gestures, and manners. The evaluation showed that stories are a very good way to teach children different social skills, ethics, feelings, and emotions; however, stories work best for children with higher functionality levels and those attracted by the stories. The main reason for the uninterested behavior was likely because of the pronunciation of the storyteller, with which several children were not familiar. Work is underway to improve on this aspect of the activities.

The song activity involved several well-known children songs such as “If You Are Happy and You Know It” or “Heads-Shoulder-Knees and Toes.” The songs were selected based on the physical-activity capabilities of the children such that the play-along physical behavior could be evaluated appropriately. This activity was the most attractive for most of the children in the group. As shown in Fig. 4, this behavior has the highest average scores for response type and time (excluding the story behavior), a very strong indication that the songs have a strong impact on children with ASD. Songs can quickly attract and retain their attention for a longer duration. Different songs with different purposes can be performed using NAO to teach children with ASD different things more quickly than normal teaching techniques.

7.1 Comparison with Conventional Technique

In order to elaborate more on the results, a comparison was also performed with the same values being obtained from the conventional teacher-based style. The values for the four variables (MEM, TPR, TMR, and NTR) were obtained through teachers’ experiences with similar activities in teacher-only settings with the same group of children. The values were found to be:

MEM: 2 TPR: 2 TMR: 6 NTR: 3

Compared with any of the outcomes in Fig. 4, these values are significantly in a lower efficiency range.

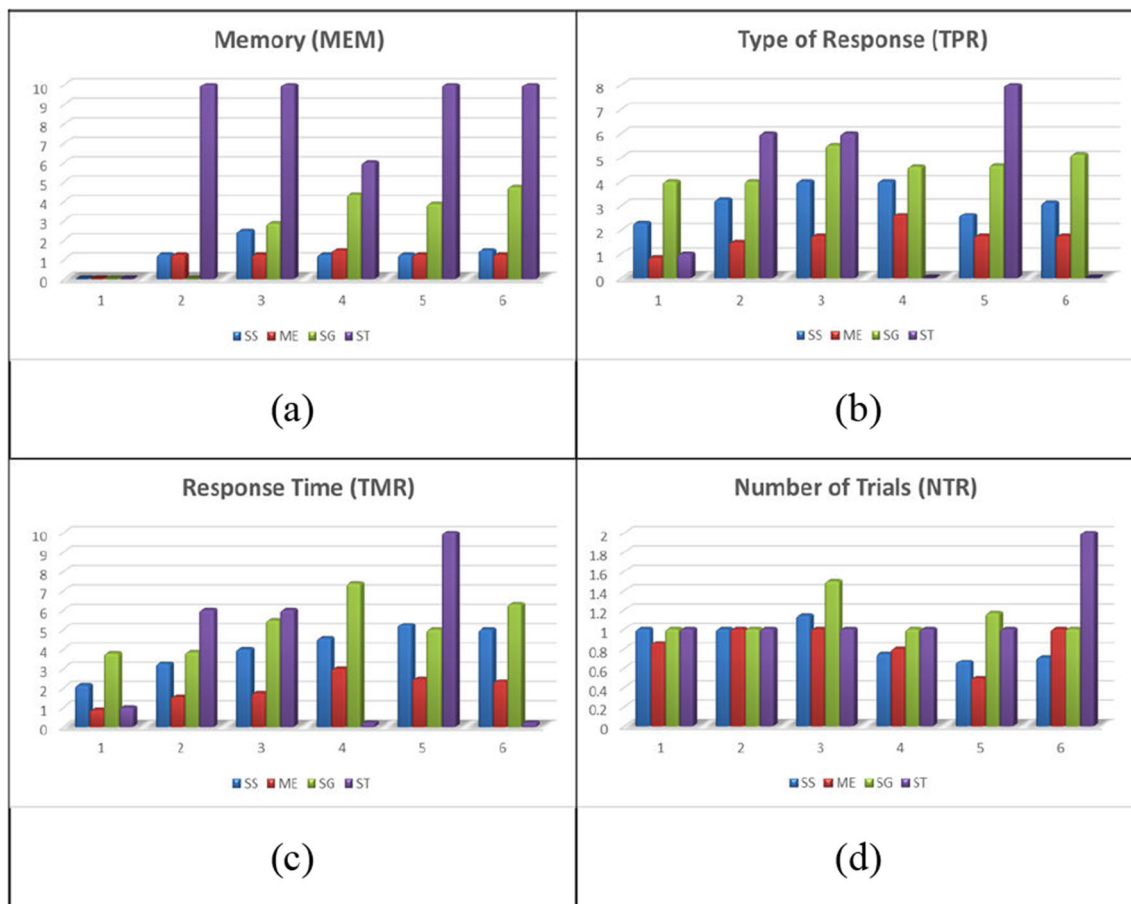


Fig. 4 Results of activity evaluations for the 4 dependent variables. **a** memory (MEM), **b** response type (TPR), **c** response time (TMR), and **(d)** number of trials (NTR). The x-axis represents the session numbers (1–6) while the y-axis represents the average performance evaluation scores

(0–10) for each group of children involved in the activity. Bar colors represent the SS, ME, SG, and ST activities by blue, red, green and purple colors, respectively

Specifically, TMR and NTR where teacher has to repeat the activity on the average 3 times before the children actually respond correctly with a response time around 6 s. The values show a large improvement when the activities are being done in a teacher plus NAO environment and consequently proves the hypothesis of significance for using such robotic toys as teachers' assistants in order to enhance the learning process. Consequently, these results have shown a promising potential in further developing and using the robotic toys for learning applications with children with ASD and other learning disabilities.

7.2 Statistical Analysis

The amount of data in this study is not too large, so any appreciable statistical trend could not be found with reasonable accuracy. However, the significance in the observations can be tested using well-known p -values calculated using T -test against a null hypothesis. The null hypothesis is proposed in this work as follows:

Null hypothesis: The use of the NAO robot added value in teacher-supervised learning activities and enhanced the learning in *at least in a linear* fashion.

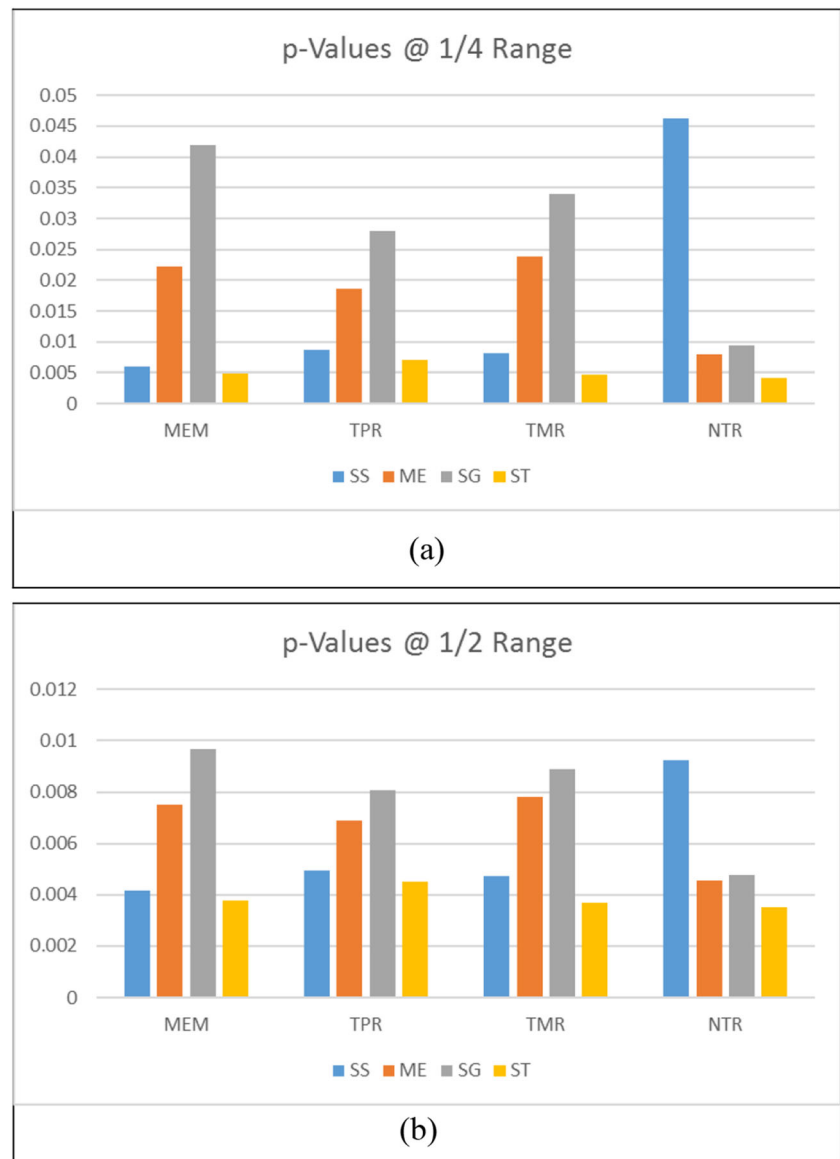
The linear learning curve is defined as follows:

$$y = P \cdot x / N \quad (1)$$

In this equation, y is the learning score (in the range of 1–10) and is similar to the scores shown in Fig. 4. x represents the trial number in any activity, while N is the total number of trials in an activity. P is a percentage scale for the learning score. Two sets of learning behaviors were evaluated using $P = 25\%$ and $P = 50\%$, representing the conservative assumptions in the learning range represented by the scores (1–10).

Figure 5 represents the same results in a categorical manner in order to illustrate the improvements in each dependent variable with respect to a specific activity. It can be seen from the figure that improvement was observed in the retention of various responses to activities for the 25% and 50% learning scenarios. In both cases, all of the p -values are below the

Fig. 5 Significance in terms of p values for the 4 dependent variables, MEM, TPR, TMR, and NTR, by various activities performed for Simon Says (SS), morning exercise (ME), song activity (SG), and story activity (ST). **a** Null hypothesis at the 25% learning curve and **(b)** null hypothesis at the 50% learning curve



0.05 standard threshold. This finding indicates that the null-hypothesis is too significant and cannot be disqualified through the experiments. In other words, the use of the NAO robot in teaching activities for children with ASD has shown significant improvements in a number of aspects of learning behaviors and confirms the confidence level for the techniques used in the context of enhancing teaching and learning experiences for these children.

Further insight into the significance level for each activity can be obtained using the 0.05 threshold and defining the relative significance (RS) as follows:

$$RS = \left(\frac{0.05 - p_{avg}}{0.05} \right) \times 100\% \quad (2)$$

In this equation, p_{avg} represents the average p value for all four dependent variables for a specific activity. Table 1 shows these values.

The above table shows the relative significance for each activity. The song activity did not perform as well, which might be because of the distraction the songs may have caused in various parameters. Figure 5 shows that the number of trials worked best for the song activity; however, the other parameters produced slightly greater results, which could be because of distracted children due to the rhythm and music. Typically, the children were unaware of the lyrics but were tuned into the music and rhythm. The interactive story activity was the best activity since it kept their attention during the story variations and interactive responses as needed by the children during the story.

7.3 Comparison with Recent Work

The most relevant and recent works reported in literature [30–35], that have also presented the use of robots and/or

Table 1 Relative significance for each activity at the two learning levels

Activity	Average at the 50% Range	RS _{50%}	Average at the 25% Range	RS _{25%}
SS	0.00577	88.5%	0.0163	67.4%
ME	0.0067	86.6%	0.0174	65.2%
SG	0.0079	84.3%	0.0268	46.5%
ST	0.0039	92.3%	0.0051	89.8%

technological tools in comparison with the conventional teacher-only methods. Ismail [30], Huijnen [33], and So [34] have presented layouts of specific activities with robotic platforms and have shown improvements in retention and understanding of activities. The numbers represent the percent improvement in activities. On the other hand, Conti [31], David [32], and Alnajjar [35], have shown superiority of the usage of robotic platforms over the human-only approaches. There findings were also presented in the form of percent improvements. These recent findings are extremely promising, and show the potential of further investment into development of these platforms. The work presented in this paper, is in agreement with these recent findings. In addition, we have shown a more quantitative, and statistical understanding of the improvement in using the robotic-platform for teaching activities with children with ASD. However, we advocate the use of these technologies in concurrence with the conventional techniques. While the above studies have shown superiority of robotic platforms over the teacher-only scenarios, there is a distinct disadvantage of using the robot-only settings; the children are in need of human company, and need to learn human values, which the robots cannot successfully teach them. However, if the same is done in concurrence with a human teacher, we have found that it reinforces the learning process while keeping the human values intact. At the same time, using the robotic platform or other technological tools for a restricted period, such as a class activity only, also prevents any affectionate attachment with the toys by children that becomes an impediment in its own in a longer run.

The p -values calculated in this work are a unique proof of significance of using the robotic toys from a counter-argumentative aspect. Essentially, the orthodox school of teaching the children with ASD relies on human-only teaching methodology and is still adapting to the technological additions. When robot was mentioned to these groups in our study, we initially faced a great deal of opposition from the teachers who were concern about children safety, familiarization levels, and friendliness of robots in such settings. On a subtle level, there was this fear of losing their jobs fearing that robots could replace them. For such contrarian audience, the counter argumentative statistical analysis will support the idea from a positive aspect. We have observed that the children really admire the use of such robotic toys in their activities and teachers also beginning to see the benefits of using such tools in making their work easier. For instance, they can now

concentrate more on the actual academic aspect of the class activity rather than struggling for a longer time to convince the child to come to the activity. Our findings are very positive in favor of using the robots for such learning endeavors.

8 Conclusions

In this paper, we have presented a short case study at a local school for children with ASD in which a humanoid robot, NAO, has been used for teaching behavioral and academic traits to children using interactive activities. Various activities and observations thereof showed that children with ASD have the ability to interact with and learn from such technological platforms more effectively than conventional teacher-only approaches.

In light of the presented findings, several encouraging observations were made. These findings, on one hand, confirmed the initial premise that we started with in this work, which is intelligently using robots to guide brain activities to be more focused and retentive. On the other hand, several quantified results confirmed various notions that noticeable memory retention enhancements could be attained for a specific activity, which was observed in reduced response time in subsequent activities and tests. The enhancement in focus and activity span were also improved; however, these were significantly subjective to the robot appearance, activities and sounds. Children who were afraid of the robot from the very beginning did not perform well. However, that changed in subsequent activities as the fear was replaced with curiosity and fun. In contrast, those who were fascinated by the robot from the beginning performed the same activities with considerably more ease and fluency than with a human teacher alone. Similar results were observed for both male and female students, provided that their initial likes related to the design and sounds were incorporated into the design.

One aspect of applying NAO or any similar technological tool in the existing institutions for children with ASD, is to make them a part of the classroom activities in addition to the usual teaching standards. This implies that the teachers can use these devices as their *assistants*, in making the children more attracted to the underlying learning activity, more focused due to a better playful peer, and more retentive due to a vivacious involvement in the activities. We do not recommend using robots-only

scenario for teaching children with ASD due to the lack of human-touch and human values that the children need to learn as part of their academic and social brought up, and to become a useful member of the society in time.

NAO robot, in general, was demonstrated to be a wonderful tool for teaching children with ASD. However, the cost of the NAO robot is a huge impediment in the way of using the robot more frequently for more children. While we continue to experiment with the robot, more economical and affordable solutions are being developed. Work is also underway with our group in order to develop low-cost devices for under-developed regions in the world to help children with ASD and similar learning disorders with limited resources. There is no doubt from these observations that NAO and similar robotic toys can be very beneficial in terms of teaching and encouraging children with ASD to learn many new and essential skills. We strongly believe that the performance enhancement of these children while learning social, communicational, and other academic activities would facilitate their personality development, serving to make them better members of society.

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