# Investigation on Requirements of Robotic Platforms to Teach Social Skills to Individuals with Autism

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**Abstract.** This paper reports on some of the robotic platforms used in the project AUROSO which investigates the use of robots as educationally useful interventions to improve social interactions for individuals with Autism Spectrum Disorders (ASD). Our approach to treatment uses an educational intervention based on Socially Assistive Robotics (SAR), the DIR/Floortime intervention model and social script/stories. Requirements are established and a variety of robotic models/platforms were investigated as to the feasibility of an economical, practical and efficient means of helping teach social skills to individuals with ASD for use by teachers, families, service providers and other community organizations.

**Keywords:** Socially Assistive Robotics, Autism.

## 1 Introduction

Children with ASD exhibit impairments in three key areas: social interaction, communication and imaginative play. For comfort, these children engage in repetitive and monotonous activities ultimately avoiding the complexities of human contact and interaction. This behavior inhibits peer interaction resulting in peer rejection. Thus a vicious cycle of inhibited social behavior during social situations occurs resulting in increased fear of these types of encounters, leading to further avoidance [24]. Appropriate social skills are crucial to academic and life success and individuals with ASD have shown success through imitation and modeling of appropriate behavior [5, 14, 22, 23, 24]. An imperative that continues to confront researchers is how can one teach and promote social interactions to individuals with ASD when human interaction creates an obstacle during the learning and application processes?

There is no single established standard treatment for individuals with ASD. Social communication approaches have used various methods such as modeling and reinforcement, adult and peer mediation strategies, peer tutoring, social games and stories, video modeling, direct instruction, visual cuing, circle of friends, and social-skills groups. In terms of educational intervention, several methods have been used

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for treating different behaviors of the spectrum, including Applied Behavior Analysis (ABA) [1], pivotal response therapy, communications interventions and DIR/ Floortime.

DIR/Floortime is a flexible, individualized intervention, which uses developmental approaches, individual differences, and relationships. The human therapist plays with the child, and tries to evolve the child's social behaviors to new behaviors with better communication skills [11]. A variety of therapies can be incorporated during this intervention including sensory-motor, language, social functioning, occupational, physical and speech therapy, along with family support and floortime play sessions. One of the advantages to this approach is that the therapies are individualized for each child. The DIR/Floortime approach with its standard use of other people and 'toys' as part of treatment sessions allows for the introduction of a robot in place of some other object (or toy) as part of the therapy process. Current research activities in such use of robots have established that robots programmed for a variety of behaviors can serve to motivate proactive interaction and mediate joint attention between the child and a peer or an adult [3, 9, 24].

SAR is a newly emerging area of robotics where robots are used to help a human through social interaction as opposed to traditional assistive tasks of physical nature, such as assembly line work [7]. SAR have been used in a number of areas including rehabilitation assistance for stroke victims [8], exercise therapy for cognitive disorders such as Alzheimer's Disease [21],and to increase socialization among residents in nursing homes [2]. Research so far has shown promising use of SAR in the treatment of individuals with ASD as an excellent assessment and therapeutic tool, especially when combined with the DIR/floortime methodology ([6, 8, 9, 12, 15, 16, 20].

Research abounds in supporting the use of novel and game-like, innovative *methods of interest* to improve student motivation, behavior, achievement and success [4, 25, 26]. Since individuals with ASD gravitate toward fields utilizing technology it seems SAR would be a logical alternative to treatment, especially if the facilitating agent utilizes minimal *human* contact.

The scientific evidence in support of the effectiveness of using robots as therapeutic agents for children with ASD keeps mounting and as a result, many researchers now believe that SAR may hold significant promise for behavioral interventions of those with ASD [3, 7, 8, 9, 10, 12, 13, 15, 20, 24].

Moreover, unlike virtual peers and other computer-aided technology, robots are mobile and quite versatile in their programming and natural environment applications. By using a versatile and mobile robot, interventions can easily be taught within the natural environment. This may contribute to not only autonomous behavior but also greater success and efficiency in applying new skills within the exact environment that presents parallel conditions under which the behavior is expected to occur (e.g., restroom, grocery store, classroom, hallway, doctor's office, etc.). Aside from being versatile and mobile, the use of Artificial Intelligence (AI) (also used for solving robotic problems) may contribute to autonomous behavior within natural environments as well. These techniques can be employed to help the robot explore its model of the world and plan its actions based on its sensory input including programming platforms, such as the traditional symbolic approach, the intelligent agents approach, the subsumption based approach, the connectionist approach, or the evolutionary approach [17, 18, 19].

## 2 Technical Platform Details

Previous research has focused on SAR interventions within therapeutic/clinical environments. These types of robots, unfortunately, are very expensive and complicated to program and use. There is a need for robotic platforms which are less costly and allow greater ease in access, acquisition, programming and practical use. Therefore, studies investigating a variety of combined SAR, AI platforms, and social scenarios within a variety of natural environments (school/ college, home, community) need to be explored. Target behaviors will include social skills that promote autonomous behavior (e.g., personal space, communication, etc.).

### 2.1 Platform Requirements

The technical platform chosen must meet several requirements in order for it to be effectively utilized in this project. One of the long-term goals of this project is that, if proven successful, the methods demonstrated can be replicated by special-needs teachers elsewhere. To this end, the technical platform chosen must be readily available and relatively inexpensive so that special needs programs can locate and purchase it. In addition, the technical platform must be easy to build, set up, and use so that those with little experience with the hardware can still use it effectively. In addition to being user-friendly, the technical platform must exhibit certain capabilities in order to convincingly perform the social scripts for the students. The technical platform must be reprogrammable so that the teachers can give it pre-made or customized social scripts to perform. Also, the platform must be mobile and able to output sound as most scripts will likely have the robot actor move around the environment and 'speak' with other robot actors. The technical platform should also be able to operate wirelessly (not physically tethered to any other device) so that multiple robot actors can freely move around in the environment. Most importantly, the technical platform chosen must appeal to the interests and imaginations of the students. The robot and its actions must capture the attention of the student without distracting or detracting from the learning experience. If a technical platform meets all of these requirements then it is a good candidate for use in this project. A thorough examination of all good candidates will allow us to choose the one which is best suited for the needs of this project. Three of the platforms used, the problems encountered and solutions are described below.

### 2.2 Lego NXT

The Lego NXT kit is a simple yet surprisingly robust robot construction platform. The NXT kit contains several pieces of hardware including a reprogrammable microcontroller unit referred to as the NXT Brick, several geared motors, an ultrasonic sensor, a sound sensor, a color and light sensor, and a touch sensor. As is to be expected with any Lego product, these components can be assembled into most any configuration using structural pieces which come in the kit. The NXT Brick also has some additional features such as an LCD screen which displays information to the user, a built-in speaker for sound playback, and Bluetooth hardware which allows the NXT Brick to communicate with other Bluetooth devices wirelessly.

The Lego NXT kit comes packaged with an easy to use graphical programming language called NXT-G. While this programming language is adequate for teaching the basics of robotic programming and imbuing robots with simple behaviors, it is ill-suited for use in programming the more complex actions required for this project. We examined several alternative programming languages for the NXT Brick and eventually decided to use leJOS NXJ due to its simplicity, familiarity, cost, and extensive documentation. leJOS NXJ is an open source Java-based virtual machine for the NXT Brick which offers a great deal of functionality even though it is (as of this writing) still in its developmental stage. The many features supported by the developers of the leJOS NXJ and the tools which are provided cover all the functionality required for this project.

We have examined several approaches of applying the Lego NXT technical platform to this project. At first, we tried loading separate, carefully timed programs into the robot actors and then had them activate at the same time hoping that they would keep in synch during the script. This approach had several drawbacks. First, it required a lot of trial-and-error to correctly get the script timings down. Second, this approach required that both robots be activated by pressing a button on their chest simultaneously - if the robots were not activated at the right time, then their scripts were automatically out of synch. Third, we found that there is very little on-board storage space for the NXT Brick so any external files (namely, sound bytes) had to be kept small and simple in order to be used. This was a serious issue since it severely limited the complexity of the scripts that could be performed to interactions which were, at most, about 10 words long. As can be imagined, this solution simply would not do. One possible workaround was to try to extend the internal memory of the NXT Brick so that it could hold larger sound files but this was abandoned after it became clear that such a solution would require tinkering with electronic hardware which only would have made it harder for other teachers to adopt this teaching strategy. The next idea examined was the use of some form of telerobotics – controlling the robot from a distance with commands. The NXT Brick has Bluetooth capability and leJOS has some rather extensive telerobotics support, so we programmed the robot to listen for instructions sent from a laptop computer via Bluetooth and respond with the appropriate action. Telerobotics extended our ability to control the robot and send information to it, but it also allowed us to control two (or more) robots from a single laptop computer which meant that a single program loaded on the computer could define an entire script. While the telerobotics approach made script writing and synchronous execution easier, it still had a major limitation: while it could send sound files over to the robot and delete them when done, the files were still limited to the size of the memory in the NXT Brick. This provided about six seconds of speech at a time, after which the computer would send the new sound file to the NXT Brick. Unfortunately, sending the new sound file took about 15 seconds to complete so conversations were, at best, short and awkwardly timed. We examined the documentation and asked the online community at leJOS if there was a workaround for this issue. In response, one of the leJOS developers modified some of the leJOS code to allow telephone-quality sound files to ‘stream’ to the NXT Brick. This effectively solved our delay problem as it meant that any size sound file (up to a certain quality) could be simultaneously sent to the brick and played.

Thanks to the leJOS developers and community, we are now able to control multiple NXT Bricks simultaneously and we can have them play any size sound file we want. This certainly makes the Lego NXT a viable technological platform for this project, but there are still several limitations which must be addressed in order to consider it the choice candidate. The speaker located on the NXT Brick is relatively small and cannot produce much noise. It can clearly be heard within about 7 feet if no other noises are present. While this may work in our situation, it is not ideal for all teaching environments. We are currently looking into commercial amplification devices which can be affixed to the NXT Brick to amplify the sound since we don't want to burden teachers with tinkering with the speaker hardware themselves. In addition, if we utilize the Lego NXT platform, we will need to create a user-friendly interface for programming the robots so that teachers can make customized scripts. If we can overcome these issues then the Lego NXT is a good choice for the technical platform for this project.

### 2.3 Robonova

The Robonova robot manufactured by Hitech is a 12 inch tall mechanical man which has a HSR-8498HB digital servo motor at every joint. It has 5 motors for each leg and 3 for each arm giving it a total of 16 joints which can produce surprisingly life-like motion. The servo motors can be controlled by programs created using Robobasic and roboscript software. The programs created using Robobasic can be downloaded to MC-3204 microcontroller through a standard RS-232 cable. The Robonova can walk, do flips, cartwheels, and dance moves by adjusting the angles of the servo motors in sequence. The Robonova kit includes everything required to assemble and operate the robot. Optional devices that can be purchased apart from the kit include gyros, acceleration sensors, speech synthesis modules and operational devices such as Bluetooth controllers and R/C transmitters and receivers. The kit comes with a remote control called IR Remocon. Programs can be loaded on it and upon the press of a button the corresponding program gets executed causing the robot to perform the respective motions. Robonova uses a 5 cell NiMH rechargeable battery that delivers around 1 hour of operational time. The unassembled Robonova kit costs $899 and the pre-assembled Robonova robot costs $1299. The Robonova is a fairly complicated robot so it is recommended that only the experienced builder purchases the unassembled Robonova kit. Robonova comes with 128KB flash memory, 4KB SRAM and 4KB EEPROM which is a relatively small memory capacity.

The Robonova kit comes with an easy to use programming language called Roboscript. Without knowing any programming language, the user can create operational subroutines by adjusting the servo motor positions and settings. The programs created with Roboscript can be uploaded to Roboremocon software on a computer which controls the robot's servos in real time via a serial cable. The Kit also includes another programming tool called Robobasic which is based on the BASIC (Beginners All-purpose Symbolic Instructional Code) programming language. The programs made in Roboscript and Robobasic can also be uploaded directly to the robot so that the robot can execute them without being tethered to the computer.

The basic Robonova kit does not include speech synthesis capability. As our project requires robots to speak for custom social interaction scripts, we needed to investigate alternative means of providing sound output from the Robonova. After some research we discovered that Robonova is compatible with the QV606M1 sound playback module chip from Quadravox, Inc. As per the research by D.G Smith, the QV606M1 will store up to 4 minutes of high-quality audio files. These can be in varying lengths and can be broken down into up to 240 separate sound bites. A free piece of editing software comes with the device. The latest version of this software and a whole series of interesting .wav sound files can be downloaded from the Quadravox site. The only disadvantage of using the QV606M1 is that in addition to the chip, one must also purchase a separate programming docking station to transfer the files from the PC to the Quadravox. The Quadravox comes pre-loaded with a large set of .wav sound files including a complete alphabet, numbers, and a lot of basic Robot related words like, "whisker", "left", "right", "infrared" etc. It also comes with the Phonetic alphabet "Alpha", "Bravo", "Charlie", "Papa", "Foxtrot" etc. and a whole set of home automation sentences, "The air conditioning", "Is on", "Is off", The alarm", "The Motion Detector", etc. Quadravox Inc. supported this project and supplied us with a QV606M1 and its programming docking bay (QV461P). We have not yet integrated the QV606M1 chip with the Robonova, so we do not know how much effort will be required of the teachers replicating this teaching method. If this effort is too extensive or requires a great deal of technical knowledge, using a QV606M1 may not be a viable option for adding sound to the Robonova and alternative sound solutions will need to be examined. If the QV606M1 can be easily integrated into the Robonova, then the ease of use, extensive motion capability, and sufficient sound capacity of this technical platform will make the Robonova a good choice for use in our research project.

### 2.4 WowWee

WowWee generously donated several robots for use in our project including a Robosapien, Femisapien, Roboquad, and several Alive Baby Animal robots. We examined these robots and while we found them to be generally entertaining and eye-catching, we also discovered that there was no easy way to reprogram them for our custom scripts. These robots may be used in some capacity to get the individuals we are working with comfortable around robots before we expose them to the robots acting out our scripts.

## 3 Experimental Design and Analysis

Studies will utilize single case study methodology ensuring social validity (pre-study interview/discussion with school, parents, teachers), treatment fidelity (procedural integrity checks, comprehension questions of participants post-intervention, training of users of robots) and inter-observer reliability (comparison of data between researchers). Baseline will include previous unsuccessful interventions, observations, interviews, and number of times the student exhibits target behavior. Post-intervention data and maintenance phases will be collected and analyzed using multiple sources of triangulated evidence (e.g., observation, interviews, antecedents, consequences, inter-rater agreement, etc.). The intervention will include a variety of investigated SAR, AI and social skill-oriented platforms. For example, in response to motion from a child, AI programs use its other sensors to approach the child up to a certain distance, or move away from the child or another robot if s/he (or it) is too close (personal space scenarios), face the child or raise its arm in a greeting and verbally respond (initiation/reciprocal communication), or toss a ball or play catch with the child (social play). This single-subject design will include comparative data and analyses of the baseline, post-intervention, maintenance phases for individual participants. There will not be a 'control group' per se, but rather analyses between each phase to determine whether the intervention (watching the robots interact) was comprehended and generalized appropriately.

In a recent pre-pilot we successfully introduced two prototypes using Lego NXT platforms. During the first phase of the project (traditional symbolic approach) we explored the internal representation of the world as encountered by the robot [18]. That is, based on sensor input, the robot constructs a model of the world based on AI search techniques and the rule base, logic programming paradigm. Various scripts of social interaction were acted out by the robot following a logical narrative. "Alphena" and "Rex" were programmed to speak to each other with minimal movement. Participants included one adolescent female student with ASD (age 16), one male adult student with ASD (age 19) and two elementary-age males with ASD (ages 8, and 10). Natural environments included school for the older students and within the home of the younger student. Where previous technology (video, verbal social script/stories, DVDs, visual/verbal prompts) had failed, outcomes yielded behaviorally observed student interest (eye-gaze followed robot's movement) and motivation (asked questions, "What are they going to do now? Will it talk? Can I hold it?") among participants as they watched the robots model appropriate behavior. Successful comprehension of robot interaction and communication among all participants ensuring treatment fidelity was measured by correctly answered post-questions to the interaction (Q: What did the robot do? A: "It walked. It talked." Q: What did the robot say? A: "Hello. Have a nice day."). The results of our pre-pilot, which was partially supported by a foundation grant from the Office of Teaching Excellence and Faculty Development at Bradley University, are certainly encouraging.

## 4 Conclusions

An imperative that continues to confront service personnel for individuals with ASD is how to teach social skills to individuals that struggle with the very *agent* needed to be social--human interaction. We believe the first step necessary for positive outcomes to this process is to establish deterministic and predictable robot behavior. A fixed behavioral routine by the robot can allow the individual with ASD to be more comfortable in 'unpredictable' situations as s/he becomes more confident with the robot in learning appropriate behavior without the complexities and anxiety associated with human contact.

Investigations need to include a variety of programming platforms to ensure parsimonious applications for schools, parents, and caregivers so that resources, such as technology-savvy teachers and students can contribute to the success of individuals with a variety of abilities who fall on the spectrum. The preliminary results of applying such robotic platforms to local schools with special education programs are very promising.

In the future stages, Bluetooth communication capabilities will allow for remote control of the robots thus enabling uninhibited interaction and data collection. Also, robots can be enabled to exhibit a more complex and sophisticated set of intelligent behaviors, which will contribute to more advanced SAR alternatives to treatment for individuals with ASD, whereby promoting autonomous behavior.

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