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# Imitation Based Training to Enhance Psychomotor Skills in Autistic Children Using a Snatcher Robot

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***Abstract*— Individuals affected by Autism Spectrum Disorder (ASD), lack in gross and fine motor skills like walking, sitting and manipulating objects using hands. There has been a consistent upward trend in the prevalence of autism from 1.16% in 2007 to 2% by 2013. A snatcher robot has been deployed to improve the psychomotor skills like grasps, directions and targeted walking of ASD affected children through imitation. Trials of pilot study were conducted for five subjects in the age group of 4 to 10 years over a period of a few weeks. The robotic training was successful in incorporating imitation capabilities and improving the psychomotor skills of the subjects and the results are favourable.**

***Keywords*— *Autistic children; psychomotor skills; robotic training; imitatio; hand-eye coordination***

## I. INTRODUCTION

Autism Spectrum Disorder (ASD) is a range of complex neurodevelopment disorders. Social impairments, repetitive and stereotyped patterns of behaviour and communication difficulties are the basic characteristics of individuals with ASD [1]. Autism manifests at the age of 2 to 3 years and if not diagnosed at an early age it makes inclusion of the child in regular routines a big challenge. Intervention provided at the formative stage helps in this process [2]. Individuals affected by ASD, lack in gross motor skills like walking or sitting and fine motor skills like manipulating objects using hands, etc. This in turn affects their language skills since they find it difficult to move their lips and jaws to articulate words [3]. As per Centre of Disease control in 2013, it was estimated that 1 in 50 children were affected by autism around the world. Comparing that statistic against that of 1 in 150 children and 1 in 68 children in 2002 and 2010 respectively, shows that there has been a drastic increase in the number of children affected by ASD [4]. There has been a consistent upward trend in prevalence of autism from 1.16% in 2007 to 2% by 2013. Studies also show that males are about 4 times more likely to be affected by ASD than females [5].

For autistic children, vision is stronger than auditory information for processing data. Research work has been taking place specifically using assistive technologies for passing information to autistic children by means of vision [6]. Automated instruction for autistic children has been experimented since late 70's and found that automated instruction machines serve as a valuable aid to teachers to teach children with autism [7]. Studies on autistic children show that imitation skills are weaker in them compared to normally developing children. It has been noted that imitation of non-meaningful actions is more difficult than imitation of meaningful actions and imitation of body movements is more difficult than imitation of actions with objects [8]. Motor imitation is an important component of both social and cognitive development [9]. Impaired motor imitation is observed as early as 20 months of age in children who are later diagnosed with autism [10]. In a study done with 32 children with ASD, under the age group of two to three years, different developmental correlates were found for different types of motor imitation. It was found that in elicitation context, attention following and imitation was a correlate. In interactive play context, social reciprocity and imitation was a correlate and in observational learning context, attention following and motor skill ability was a correlate of imitation [11]. Various levels of technologies viz. 'low', 'mid' and 'high' have been incorporated into different aspects of daily life training for autistic children. 'Low' technology involves low cost, easy to use visual support strategies that do not make use of any type of electric or battery operated devices. Simple battery operated devices are used in 'Mid' technological systems. 'High' technology involves training with high cost technologically complex support strategies [12].

These days, robots serve as a potentially promising approach for intervention and most importantly as a medium using which children with autism can interact effectively. It is accepted as a therapeutic modality for improving social competence in them. The main reason why robotic kits work with children with ASD is that robots do not react to children's moods and meltdowns, it does not have the capability to judge or bully, it cannot make the children feel the pressure or the anxiety and will act exactly as the child wants it to act, without any personal feelings. Robots are very convenient since they are consistent and create a sense of calmness for children with ASD, who despise change in anything [13] [14].

Project AUROSO uses many robotic platforms for this purpose based on treatment using Socially Assistive Robotics (SAR). 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. Nikolopoulos et al. investigate the feasibility of an economical, efficient and practical means to teach social skills to individuals with ASD that can be used by all,


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including parents, teachers, service providers, etc [15]. One of the platforms that has been investigated and proven to be robust and useful is Lego NXT . NXT Robotic kits have been used in a few experiments with a group of children with autism to foster collaboration between them. In a voluntary after school robotics class, seven children with ASD were taught to program the robots and play with it. It was found that after the trial period of eleven sessions that there had been a significant increase in the collaborative behaviours among the children. They also interacted when asked to draw on group-shared pieces of paper, showing that they were generalizing their behaviours learnt from the robotic classes [16]. Eminent research by Legoff proved that after the LEGO therapy the children displayed more positive social behaviours and less negative social behaviours [17]. It was also found by Legoff and Sherman that after the Lego therapy sessions, children performed significantly better on standard social behaviour tests than children who attended more traditional autism therapy sessions for the same period of time [18].

Jillian et al. developed a system in which a Nao humanoid robot provides graded cueing to children with autism. They closely examined each child who played an imitation game with the robot, which was programmed to imitate 25 different arm poses. When a child imitates the pose correctly, the robot gives a positive verbal feedback, nods and flashes its eyes green. If the child fails to imitate, the robot offered varied prompting. At first only verbal cues are provided followed by detailed instruction and demonstration of the cues. The results of the study show that, the children who received varied prompting improved or maintained performance, while the children who did not receive varied prompting regressed or remained the same [19]. Other important challenges of an autistic child are complexity and unpredictability of social interactions. In a study done with two pairs of children with ASD, where one set is paired with a human mediator and the other with a mobile robot called Tito, showed that the latter had increased shared attention (visual contact, physical proximity) and imitation of body movements and facial expressions for example smile, cry, etc. than the former [20].

Enhancement of the imitation skill in individuals with autism can serve as a tool to improve psychomotor skills and communication skills. Hence, a system, which assists therapists to impart imitation skills, has been addressed in this paper. The scope of the system is to improve the psychomotor skills like grasps, directions, backward walking, etc. through imitation and in turn improve the vestibular and proprioception aspects of children with ASD.

## II. DEVELOPMENT OF SNATCHER ROBOT

The objective of the work is to develop a robotic training system that can carry out activities, which will inculcate imitation in children with autism. A mobile robot which can be programmed to carry out different tasks, can be made use of for this purpose. A snatcher robot has been developed using the LEGO mind storm kit NXT 2.0. which is shown in Fig.1. It is an autonomous mobile robotic arm that can find, pick up and place objects. It makes use of two NXT interactive servomotors to control the belted wheels, allowing the robot to move in any direction. The specially designed multifunctional grabber for grabbing and lifting objects employs only one motor to perform both the activities. The ultrasonic sensor provides vision to the robot which helps the robot avoid obstacles, sense and measure distance, and detect movement. The controller console of the robot is an intelligent computer-controlled LEGO brick that features a 32-bit microprocessor, a large matrix display, input and output ports, and a speaker. The robot has been programmed to perform certain tasks for children to observe and imitate.

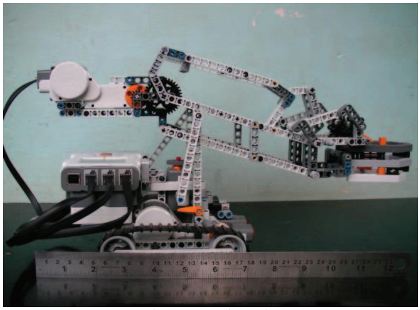


Fig. 1. Snatcher robot

## III. TRAINING USING THE ROBOTIC KIT

A pilot study to verify the feasibility of using a robot for training children with autism to impart imitation skills, was undertaken. The scope of the training includes acquaintance with the robot, enhancing or developing imitation skills, teaching the concept of directions and development in vestibular aspect by teaching backward walking. A typically developing child acquires imitation skills since its infancy, naturally.

Training and preliminary trials of pilot study were conducted using the above-mentioned setup in one of the physical therapy centres in Thanjavur, Tamil Nadu, India under the supervision of a speech therapist. Five subjects in the age group of 4 to 10 years were considered for the trials with due consent from their parents. Out of the five subjects, two were girls and the rest were boys. All of them were previously diagnosed to be autistic by 'Child Trust Hospital', in which a team of paediatricians, psychologists and psychiatrists work together. They referred these children for occupational and speech therapies.

The robot was pre-programmed with four different activities for the subjects to imitate. The training procedure followed for every subject was the same and is as follows; first, the subject was made to stand beside the robot parallel to it and this is taken as the home position. The first program i.e. the program to pick up a basket and place it at 90° to the right is selected and the robot starts to execute the same action. The robot from the home position moves forward to detect a basket in front of it using the ultrasonic sensor. Once the basket is detected, it moves in the reverse direction for a pre-programmed distance, moves forward again and picks up the same. Then the robot turns right 90°, moves forward for a pre programmed distance and places the basket on the ground. After a small pause, it retraces its path to its home position in a reverse motion. The '90° left' program is very similar to the '90° right', except that it places the basket 90° to its left. In the '180° rotation' the robot picks up the basket just like previous programs but turns 180° right and places the basket at the diametrically opposite side of the home position. In the 'ball basket' program, the basket is placed at 90° to the left of the robot and the robot picks a ball kept in front and follows the same path of that of '90° left' program and drops it in the basket.

The training was given to the subjects in a language that they could understand. Initially only one task was to be done by the subject. The same task was repeated a number of times for the subject to imitate. Only when the subject has learnt to do a particular task properly with minimal assistance, the next action was taken up. The intention of giving repeated training is to increase the familiarity with the commands and most importantly reduce the delayed perception. Depending on the mood, cooperation, focus & attention of the child and the appointment with the therapist, the training sessions were approximately 20-30 minutes each, one session per week. The total duration of training varied with subjects based on their regularity. Every session was structure oriented to make it easier for the subject to adapt and learn. In every session, the learning of the previous session was practiced before moving on to the next task. The imitation activities were designed to achieve:

1. Improvement in non verbal imitation
2. Enhance hand-eye coordination
3. Balanced body movements and backward walking

The first task that was taught was '90° right' then followed by '90° left, '180° rotation' and 'ball in the basket'. The basic objective of the training is that with enough practice the subjects would learn the art of imitation and in parallel enhance their psychomotor skills. The procedure of the trials conducted for the five subjects is explained below:

Initially, the robot was placed in parallel to the subject, both facing the same direction. The subject was asked to identify the robot. If the subject was not able to do it, then the therapist or the mother pointed to the robot and brought the subject's attention to the robot. After the basic step, the activities were introduced one after the other. The robot executed the first task with the subject only watching and not following the robot's actions. This was also accompanied by oral explanations and instructions from the therapist. Then the same task was repeated by the robot, but this time with the subject imitating the robot's actions. If the subject was unable follow it, then the mother or therapist will assist him/her to complete the task and again the same procedure is repeated until the subject is able to do it individually. If the subject succeeded without assistance then a tick ✓ was marked in the '90 right' cell of the trial sheet, or else it was marked it with a ✖. If the subject needed teach support and the therapist / mother holding the subject's hand, walked physically and imitated the actions of the robot, then the cell was marked with $✓_{\text{Teach}}$. When the subject just needed a touch cue by therapist/parent then the cell was marked with $✓_{\text{Touch}}$. If the assistance provided was oral cues then the respective cell was marked with $✓_{\text{OC}}$. As the subjects succeeded in doing one task, next task was taught. The same procedure was carried out with each of the five subjects individually and all the outcomes were tabulated for further studies. Specific particulars of observations on the behaviour of subjects were noted down for reference purposes. A sample trial sheet shown in the Fig. 2., consists of a table used to record the outcomes of all the activities created for the subjects using the snatcher robot. Each subject had one dedicated trial sheet and the outcomes were tabulated for all the sessions conducted.

Sl No:
Name:
Age and DOB:

| Sessions | Trials | Identify | 90°Right | 90° Left | 180° | B B |
|---|---|---|---|---|---|---|
| Session 1 | 1 | ✓ | ✖ | | | |
| | 2 | ✓ | ✓ Teach | | | |
| | 3 | ✓ | ✓ Touch | | | |
| | 4 | ✓ | ✓ OC | | | |
| | 5 | ✓ | ✓ | | | |
| Session 2 | 6 | ✓ | | ✓ Touch | | |
| | 7 | ✓ | | ✓ OC | | |
| | 8 | ✓ | | ✓ | | |
| Session 3 | 9 | ✓ | | ✓ | | |
| | 10 | ✓ | | ✓ | | |
| | 11 | ✓ | | | ✓ | |
| | 12 | ✓ | | | ✓Touch | |
| | 13 | ✓ | | | ✓ | |
| | 14 | ✓ | | | ✓Touch | |
| | 15 | ✓ | | | ✓ | |
| Session 4 | 16 | ✓ | | | | ✓ |
| | 17 | ✓ | | | | ✓ Teach |
| | 18 | ✓ | | | | ✓ Touch |
| | 19 | ✓ | | | | ✓ OC |
| | 20 | ✓ | | | | ✓ |

B B - Ball Basket
✓ - Success
✓ Teach - Teach support
✓ Touch - Touch support
✓ OC - Oral cue
✖ - Failure

Fig . 2. Trial sheet

## IV. Results And Discussions

### A. Observations

The progress of learning by each subject is measured across 9 sessions in terms of success percentage, which is calculated from the ratio of successful trials without any assistance to the total number of trials recorded in the trial sheets of subjects. The number of trials per session and number of trials per task varied with subjects, as it depended on the mood, response, task and learning rate of a subject. Fig. 3. shows progress of the subjects through the 9 sessions.

It can be seen that Subject 1 had no success at all initially, as the success percentage is zero on the first session. It gradually increased to more than 50% on the second session and eventually reached the top score of 100% on the 9$^{th}$ session. The dip in the 4$^{th}$ session attributes to learning a new task in that session. Similarly, Subject 2 showed failures on the first two sessions and then with repeated practice was almost able to the reach top score. It can be seen that this subject showed consistent improvement throughout the training. Despite having more than 50% success in the first session, subject 3 needed minimal assistance towards the end of the training with a success percentage of 80. Subject 4's performance is seen to be very platonic, as the success percentage in every session seemed to vary with several dips and peaks throughout the training. On the 9th session it is seen that the success percentage has increased to 47% from the 13% on the first session. Subject 5 on the other hand, is seen to have a consistent improvement from 25% on the 1st session to 86% on the 9th session.

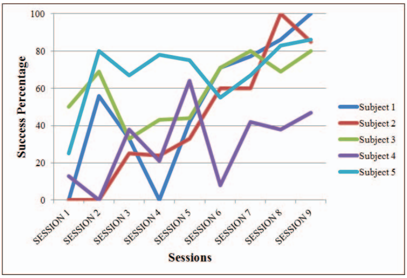



Fig. 3. Progress graph of subjects

The success percentage considered here includes only the successful trials without any assistance and the dips in the graph attribute to new learning associated with a new activity in that session.

It is clear from Fig. 4. that the tasks '180°' and 'Ball Basket' were carried out more easily than the first two tasks '90° right' and '90° left' since the success percentage on the former is more compared to the latter. It is also evident that the subjects progressed as the activities evolved from directional movements to the task of ball basket, this maybe because '90 right' and '90 left' were the first two activities that were introduced to the children and the rest were introduced later in the training. Hence, they were able to perform better due to repeated practise. On an average, the subjects have a 71% success rate at the end of the training (in 'Ball Basket' game). It can be seen from the graph that Subject 1 found the '90° left' task to be the most difficult to carry out than the other tasks. Subject 2 has shown a consistent improvement throughout the training with the success percentage increase from 30% to 82%.

In case of Subject 4, it was found that towards the end of the training the success percentage increased to 56% (in "Ball basket task"), in spite of requiring more assistance in the previous tasks. Subject 3 performed all the tasks quite well except for '180°' and subject 5 found it difficult to perform '90° left' task, than the other tasks.

Fig. 5. illustrates the success with assistance (SwA), success without assistance (SwoA) and failure of each subject for all the four activities. Figures 5a, 5b, 5c and 5d show the graph for, '90° right', '90° left', '180°'and 'Ball basket' activities respectively. Fig. 5a. shows the graph of '90° right' task. It can be seen that all the subjects required assistance to successfully complete a task and subjects 1, 2 & 4 have also recorded failures even after providing assistance. Similarly, figures 5b and 5c are the graphs for '90° left' and '180°' tasks respectively. These show that all the subjects needed assistance to compete the task but the failure percentages have reduced. Only subject 1 & subject 4 have recorded failures in '90° left' task and subject 2 & subject 4 in '180°' task. The failure percentage in Fig. 5c. i.e. '180°' task , is lesser than that of '90° left' task. In 'ball basket' task as shown in Fig. 5d., no failure is recorded. This shows that as the sessions proceeded from '90° right' to 'Ball Basket' task, the performance of the subjects improved as they were able to follow instructions and perform the tasks with minimal assistance. It also indicates that during the trials, the overall skills in the subjects have developed significantly though each subject showed a different rate of improvement.

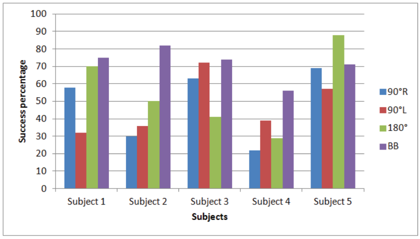


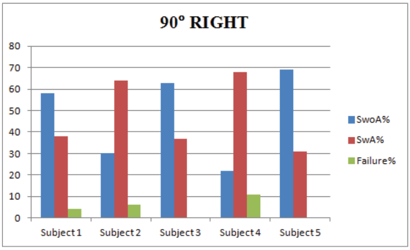

Fig. 4. Success of the subjects in different activities

Throughout the training, each and every child has shown improvement and this improvement has been recorded for further studies. As a sample, detailed progress graphs of subject 1 and subject 5 are graphically represented as shown in Fig. 6. and Fig. 7. respectively. These graphs show the percentage of failure, touch assistance, oral cues and success without assistance of the subjects throughout the training sessions.

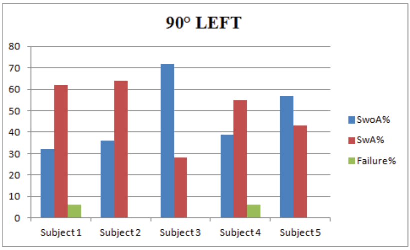
It is observed from Fig. 6. that, subject 1 had recorded failure in session 1,4 and 6. Though he required touch assistance and oral cues to perform the trails correctly, it could be seen that it declined gradually and became zero by the 9th session. He was able to carry out the task without any assistance towards the end of the training, which is reflected by the full success line reaching 100%.

*B. Effectiveness of training through the robotic kit*

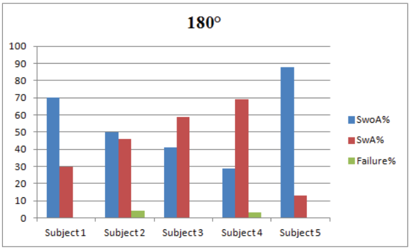
As can be inferred from the above sections, robotic training is successful in teaching the imitation concept and enhancement in vestibular awareness. This is further ascertained by the assessment of the therapist and opinions of the parents. The therapist observed that the training improved the motor skill abilities and vestibular skills in the children. There was also reduction in stereotypical movement. The children were able to walk backwards which the therapist or the caregivers were not aware of previously.



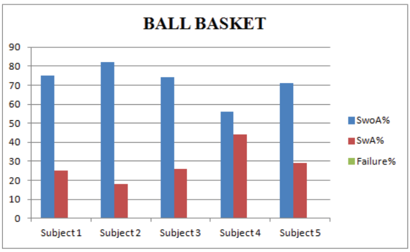

(a)




(b)




(c)




(d)

Fig. 5.Success with assistance, success without assistance and failure for all the four activities

Similarly, all the children were able to pick up their respective baskets and place them physically with their hands by imitating the robot. This also showed the increase in the hand-eye coordination and visual tracking which is considered to be a challenge in children with ASD. Towards the end of the training they were able to comfortably work with the robot for longer periods without hesitation even though the activities kept varying. This shows that their acceptance and adaptability to a given situation had improved. The most important aspect was that there was an increase in the retention power and concentration of the subjects. This was proved by the fact that they were able to perform all the activities correctly on the confirmation trial held after a few weeks of break.

The therapist attributed the success of the training in imitation skills to active learning through the robotic kit. The parents also reported that the children were able to generalize the concept of picking up and placing things in everyday life.

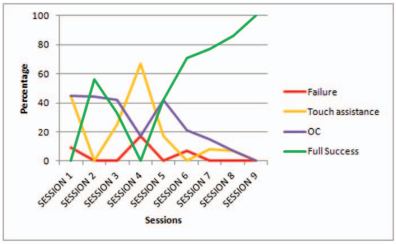



Fig. 6. Progress graph of Subject 1

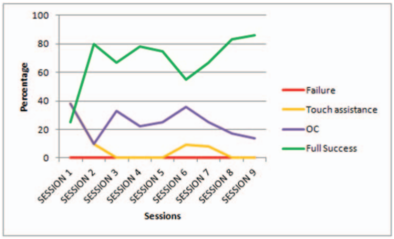



Fig. 7. Progress graph of Subject 5

## V. CONCLUSION

The need for developing and using additional kits for inculcating imitation skills in ASD affected children is evident. It is a proven fact that children are attracted towards robot and robot like features. Hence, incorporating imitation skills through robotics training is a working methodology and the results are favorable. On analyzing the out comes from the trials, it can be seen that there is a significant improvement in imitation skills and motor skills. The subjects successfully imitated the snatcher robot and have been able to generalize the concept of picking up and placing things in everyday life. The feedback from the therapist and the parents led to conclude that the robot based training helps the children with ASD to improve imitation skills, hand-eye coordination, daily life activities and collaterally reduce the fear component. The findings were encouraging and hence the authors are motivated to take up the research forward and develop training systems that would help individuals with ASD to lead an independent life.

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