# A Study Of Auti: A Socially Assistive Robotic Toy


Helen Andreae
VUW
P. O. Box 600
Wellington, NZ
+64 21 188 7257
Helen@andreaedesign.com

Peter Andreae
VUW
P. O. Box 600
Wellington, NZ
+64 4 463 5834
Peter.Andreae@vuw.ac.nz

Jason Low
VUW
P. O. Box 600
Wellington, NZ
+64 4 463 6721
Jason.Low@vuw.ac.nz

Deidre Brown
VUW
P. O. Box 600
Wellington, NZ
+64 4 463 4720
Deidre.Brown@vuw.ac.nz



## ABSTRACT

This paper presents an evaluation of the effectiveness of a new socially-assistive robot, Auti, in encouraging physical and verbal interactions in children with autism. It aims to encourage positive play behaviors such as gentle speaking and touching, with positive reinforcement through movement responses, and to discourage challenging behaviors, such as screaming or hitting through the removal of the reinforcing movements. This study evaluates the design by comparing a fully-interactive Auti to an active-only version, which does the same movements but does not respond to the child. Results from 18 participants indicate that the Interactive Auti does encourage positive behaviors more than the Active-only version. However, further design is needed around addressing problematic behaviors.



## Categories and Subject Descriptors

K.4.2 [**Computers and Society**]: Social Issues – *assistive technologies for persons with disabilities.*

J.4 [**Social And Behavioural Sciences**]: Psychology

## General Terms

Design, Experimentation, Human Factors.

## Keywords

Socially Assistive Robots, Toys, Autism, ABA Therapy.


## 1. INTRODUCTION

Autism is a prevalent and growing developmental disorder. One in 50 children in America are diagnosed with an autism spectrum disorder (ASD). Individuals present with deficits in three areas: impaired social interaction, impaired communication, and repetitive and restrictive behaviours and interests. Difficulties with social interactions, such as understanding and controlling body language, are a large part of the presentation of ASD. The etiology of ASD is still unclear. There are multiple approaches seeking to explain the disorder from various research perspectives, ranging from genetic and neurobiological approaches to cognitive and social theories. The disorder's heterogeneous nature is likely to reflect multiple etiologies resulting in similar behavioural presentations.

Considering the lack of an evidence-based unifying theory and the variability in the presentation of the disorder, it is not surprising that there are many available treatments – the survey in [4] identified 111 different autism treatments. Although many autism treatments are controversial and not yet backed by experimental evidence, Applied Behaviour Analysis (ABA) is well researched, with 40 years of development, and experiments have shown clearly positive results. It is considered the most effective therapy for ASD [8]. ABA is an approach to therapy arising out of the behaviourist perspective of psychology and is, in essence, the application of operant conditioning. When applying ABA to a case of autism, the behaviours of the child are analysed and specific goals are set to help improve behaviour [7]. Therapists will prompt a desired behaviour. If the child responds, the reward is offered; thus reinforcing the desired behaviours. If the prompts are disregarded, rewards are withheld [12].

The use of robotics in teaching children with autism is a recent area of exploration. The emerging field of socially-assistive robots addresses robots that help develop or aid social interactions for a range of users such as the elderly, stroke patients, and those with cognitive disorders [3]. It is important to investigate this area, as it may offer a more economical and readily available way to assist those with autism.

Children with ASD tend to show a preference for interacting with inanimate objects over people [1]. Socially-assistive robots are particularly interesting for teaching those with ASD as robots may offer an intermediate step between inanimate objects and people, because robots have a mixture of characteristics of inanimate objects and human agents. Robots may allow some elements of social interaction without confusing the child with an overwhelming onslaught of social stimuli. Also, by pairing the social stimuli with stimuli that are already attractive to the child, robots can draw more overall attention. Further, Diehl *et al*'s [2] analysis of current research found the literature suggests that agents with robotic characteristics are preferred over both passive toys and humans, at least initially. They also found that robots could be effective in eliciting behaviours, although the research was predominantly theoretical. Interestingly, they only found one robot that provided reinforcement for behaviours to teach a skill. So they concluded that this is an area that merits more research, particularly given that ABA-based therapies are dominant in the treatment of autism.

Although evidence for robots being a successful medium for teaching children with ASD is building [6, 13], the research is still new and has limitations. Many studies in robotics have particularly low participant numbers, typically between 1 and 5.




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Also, as pointed out in [11], much of the robotic research is from an engineering perspective which has different priorities and methods from psychology. The majority of the studies are characterised by having few or no human controls, no qualifying diagnostic tests for the participants, and are focused on the robots' performance rather than the children's. To find how children are being affected, there is a need for more careful studies in this area.

Auti, the focus of this study, is a socially-assistive, robotic toy designed to help encourage positive play behaviours and dis-courage problematic behaviours (See Autitoy.com). Auti employs ABA principles, applying reinforcement through movements when positive play behaviours like talking, patting or initiations occur; and removing reinforcement by stopping when challenging behaviours like screaming, hitting or throwing occur.

Auti was designed from the start for children with autism, taking into consideration the role of the face, sensory difficulties, and difficulties with imaginative play. Auti has contrasting textures – fluffy soft fur and smooth legs – to encourage sensory exploration. Its form reflects 'cute' elements which have been shown to help engage and focus attention[9]. To alleviate anxiety or confusion caused by facial stimuli, the toy does not have a face. The lack of a face, in conjunction with Auti not looking like any particular animal, also helps remove external expectations of how the toy should be played with, making it easier for a larger range of play to be accepted and encouraged. It also means that children do not have to understand Auti as a representation of something else to be able to play with it. Auti does however move with animal characteristics to make it easy for children who do understand representation to play with it as if it were an animal.

Auti can move each of its four limbs independently in movements which combine up-down and in-out motion. It can detect different types of physical interaction. Gentle physical contact is detected using a proximity sensor that is triggered when a person's body comes close enough to touch the fur. Auti responds to gentle touching or speaking with one of six distinct movement responses. Shouting, screaming or rough physical interactions result in the toy freezing for 5 seconds.

After it has finished its response, Auti enters a resting state unless it is reactivated. The aim of this state is to encourage initiation – little movements indicate that the toy is still responsive, but requires the child to initiate interaction with touch or voice. If Auti is upside-down, it waggles its limbs gently until it is turned back over. Auti also has a remote control that an instructor can use as a manual back-up to control Auti in the event that any sensor fails. During the experiments, the sound detection was done manually through the remote, since reliable automatic detection of someone talking quietly close-up versus someone shouting from a distance is extremely difficult.

This current study explores the effectiveness of applying reinforcement through the medium of Auti. The study also asks how the children classify Auti (as an animate entity or as an object). The first hypothesis of this study is that the children using Auti will display more targeted positive behaviours and less targeted challenging behaviours than the control condition. The second hypothesis is that the children using Auti will use more anthropomorphic/zoomorphic language and display more social behavioural interactions than the children in the control condition.

## 2. Method

The study assessed the children over a 2 ½ - 3 hour structured play session during which children played with three toys. The protocol was flexible to simulate how a child might play in a standard home environment. If the child wanted to keep playing with Auti or one of the other toys or if they really wanted a break, the protocol was adapted. The children were split into two conditions. The first condition used the full Interactive Auti, which responds to a child's behaviour as described above. The second condition used Auti running an active (but not interactive) program. Active Auti ignores all sensors, and cycles through its movements randomly so that no distinguishable pattern can be predicted. Active Auti performs the different movements in the same frequencies as Interactive Auti does during average interactive play. At the end, children in the active condition were given Interactive Auti to see if there were any differences in their play behaviours – providing both between-subject and within-subject comparisons.

### 2.1 Participants

Participants consisted of 18 children with an autism diagnosis between the ages of 4 years 6 months and 8 years 2 months. Four participants were female. All participants had a formal autism diagnosis from a paediatrician and this diagnosis was confirmed with the Gilliam Autism Rating Scale Second Edition (GARS-2). Nine participants were assigned to each condition and were matched across the conditions according to their ages, their scores on the GARS-2 test, the Peabody Picture Vocabulary Test (PPVT) and the colour progressive matrices test (CPM). Table 1 shows how the means and standard deviations of matching criteria along with the significance value from the between-subjects t-tests. The table also shows that there was no significant difference between the way the groups interacted with a walking puppy toy (WP) which was used to compare the children's general play behaviors.

**Table 1. Group differences**

| | Int. $\mu$ | Int. $\sigma$ | Act. $\mu$ | Act. $\sigma$ | Sig. |
|---|---|---|---|---|---|
| GARS-2 | 90.89 | 15.35 | 90.00 | 16.03 | .91 |
| PPVT | 97.40 | 34.86 | 89.60 | 26.65 | .70 |
| CPM | 13.56 | 13.82 | 14.78 | 14.61 | .86 |
| AGE | 6.44 | 1.25 | 6.50 | 1.23 | .92 |
| WP | 50.78 | 57.08 | 58.44 | 50.30 | .77 |

### 2.2 Procedure

Before the main experiment, the instructor conducted a 45-minute interview with the parents and a half hour interview with the children where background information and data for matching was collected. The trials took place in the child's home to ensure that the children were in an environment where they felt comfortable, removing the difficulties some children have with new places. Video cameras were set up in the room from two angles and turned on before the toys were introduced.

To gauge how the child played with standard active toys, the instructor initially gave them a walking puppy toy to play with for up to 10 minutes. The toy was a modified 'Furreal Friends Walkin' Puppy, the modifications removed the all the puppy sounds as well as the 'pat switch', resulting in a dog toy which walked indefinitely when turned on.

Auti was then introduced and the dog was taken away. The child had three play periods with Auti over an hour and a half. For the first 15 minutes, attention was directed toward Auti. The child was then allowed to keep playing with Auti or choose another preferred activity. After 10 to 20 minutes, they were then redirected back to Auti. This was repeated twice, resulting in three

Auti-focused times. This flexible protocol was used so the child felt they were in control and because behavioural shaping only works if the child desires the 'reward'.

Throughout the first section of the play time (~15min), Auti was referred to as an 'it', unless the child referred to Auti as an animal or a he/she. In which case, the instructor then responded in kind from that point. In the second two sections, "support toys" of a brush, a blanket and blocks were introduced and the instructor referred to Auti as a 'he' to see if this changed how the child classified the toy.

The children in the control condition were also given the interactive version of Auti for up to 10 minutes to see if their behaviours were different. After the last session playing with Interactive Auti, Auti was taken away and a realistic looking "sleeping dog" (Perfect Petzzz® chocolate lab) was put by the child to see if any behaviours seen with Auti were generalised.

The video recordings were coded for positive and negative physical and verbal interactions and their causes (own initiative vs. prompted by instructor). One "physical interaction" was counted every time the child touched and released the toy. For longer interactions, one "physical interaction" was recorded every 2 seconds the child was in contact with the toy. One "verbal interaction" was counted for every continuous verbalization followed by a break. The coding also recorded how the children classified Auti, and whether they engaged in extended play with the toy. Classification was counted every time the child referred to the toy using anthropomorphic or zoomorphic language or they behaved towards the toy as if it were 'alive'. Extended play was recorded when a child went beyond simple action-response play. This was counted the first time a new extended play occurred, or if the extended play had not occurred for 3 minutes.

## 3. Results

In all the analysis below, the interactions prompted by the instructor were disregarded. Because the skew and kurtosis of the collected data were outside of the normal range, and Kolmogorov-Smirnov normality tests came back as significant, the data was analysed with a Generalized Linear Model (GLM) using a Poisson regression with a log link function, which is a common non-parametric test for count data. Significance in GLM is tested using The Wald statistic (a particular form of a $X^2$ statistic) on the slope coefficient of the GLM.

**Positive and Negative Interactions**.

As the hypotheses predicted, significantly more positive verbal and physical interactions occurred with Interactive Auti than with Active Auti ($p \leq .001$) (Table 2). This was also the case for the children who played with both toys. Paired sample t-tests showed they displayed significantly more positive interactions when playing with the Interactive Auti than they did when they played with the Active Auti ($p = .05$) (Table 3). The comparisons are still statistically significant when the positive interactions are broken down into the verbal and physical interactions. This was also the case for children who played with both toys.

There was no significant difference between the number of negative interactions displayed in the Interactive condition and the Active condition, nor when the physical and verbal interactions were analysed separately were any significant results found. (Table 2) This was also the same for the challenging behaviours displayed by the children who played with both versions of Auti.

**Classification and Extended play occurrences**

A significant difference was found between the number of times the children categorised the Auti as 'animal like' in the Interactive and the Active conditions ($p \leq .001$), with more occurrences in the Interactive condition. There were however no significant differences in classification occurrences with children who played with both toys (Table 4). Instances of extended play occurred significantly more in the Interactive than the Active condition ($p \leq .001$) There were however no significant differences in the number of times the children who played with both Auti's extended their play (Table 3).

**Table 2. Between-subject means and test statistics**

| | Int. μ | Int.σ | Act. μ | Act.σ | $X^2$ | Sig. |
|---|---|---|---|---|---|---|
| +total | 222.89 | 151.68 | 98.11 | 111.22 | 412.84 | .001 |
| +physical | 197.33 | 137.26 | 98.11 | 111.22 | 287.99 | .001 |
| +verbal | 25.56 | 36.23 | 0 | 0 | - | - |
| -total | 4.33 | 7.67 | 4.67 | 8.27 | .11 | .73 |
| Classific. | 8.56 | 11.00 | 1.44 | 2.24 | 35.19 | .001 |
| Extension | 5.89 | 8.58 | 1.89 | 2.42 | 16.64 | .001 |

**Table 3. Within-subject means and test statistics**

| | Int. μ | Int.σ | Act. μ | Act.σ | *t* | Sig. |
|---|---|---|---|---|---|---|
| +total | 122.00 | 94.22 | 40.67 | 54.45 | 3.77 | .05 |
| +physical | 108.89 | 87.32 | 40.67 | 54.45 | 23.35 | .01 |
| +verbal | 13.11 | 13.46 | 0 | 0 | - | - |
| -total | .22 | .44 | .44 | 8.40 | 1.48 | .18 |
| Classific | 7.22 | 15.80 | 1.44 | 2.24 | 1.06 | .32 |
| Extension | 3.33 | 3.91 | 1.89 | 2.42 | 1.13 | .29 |

## 4. Discussion

The primary aim of this study was to explore whether ABA principles of reinforcement, applied through a robotic toy, could be effective in encouraging and discouraging targeted behaviours in children with autism. The results of the experiment confirm that positive behaviours can be encouraged through a robotic toy. The high variability in the data is not particularly surprising given the heterogeneous nature of ASD. Different presentations of the disorder are likely to significantly affect the way in which children play with the toy.

As this study hypothesized, the children with Interactive Auti displayed significantly more targeted positive behaviours than with Active Auti. This was particularly prominent in the verbal interactions where no verbal engagement was observed in the control condition. This aligns with the research on ABA: offering a reward for behaviour will help elicit it. Moreover, it tells us that rewards delivered though the medium of a robot can be effective. Though this may seem an obvious result, given that children with autism respond to stimuli a-typically, it would be an unreasonable assumption to consider this obvious. The experiments also tell us that responsive movements of a robotic toy are enough of a reward compared to non-responsive movements to encourage positive interactions. This is an important point, not just for Auti but for all such robotic toys, considering the review in [2], which pointed out the lack of research and development around robotics incorporating ABA principles.

The main experiment addresses between-subject comparisons. But it was also interesting that, in spite of fatigue and exposure to the non-interactive version, the children who played with Interactive Auti after Active Auti also displayed significantly more positive interactions with Interactive Auti. It would be interesting to see if within-subject experiments that controlled for order effects had the same results.

There are limitations to the interactions displayed by the children. Of the positive verbal interactions, 10 of the 18 children interacted only using the word 'hello', which was the word the instructor used to demonstrate the interaction. Physical interactions were similarly repetitive. It is possible that the varieties of interactions could be increased, if Auti could distinguish more finely between different types of positive interactions. The analysis part of ABA is crucial to its effectiveness [10]. Currently, no robots, including Auti, are able to analyse and address behaviours with the skill of a human. However, this level of analysis is not necessary as the robots are the medium for teaching, not the teacher. Still, the more types of interactions robots can distinguish or sense, the more behaviours a program can target.

The negative interactions did not significantly differ between the conditions. There are several possible reasons why the negative interactions did not decrease. Firstly, children seemed to be confused by the toy stopping. They did not appear to know whether it was purposely meant to stop or whether they had broken it. And since challenging behaviours seldom occurred, they had little opportunity to learn the pattern of the toy's responses. Secondly, children may not have viewed the movements as a strongly rewarding; so they didn't care if they were removed. Thirdly, reducing challenging behaviours can be more complex than eliciting new behaviors. ABA has had good results when dealing with challenging behaviours, but employs careful analysis and develops targeted strategies.

Like the study in [5], this study found that more animal-like classifications occurred with the Interactive toy than with the Active one. This result is of interest for two reasons. It helps us understand how the children view the toy, and it raises the possibility of using Auti, or other robotic toys, in similar ways to how animals are used in Animal Assisted Therapy (AAT). Although the results show that the children are distinguishing between the Interactive and Active Auti, and acting more socially toward Interactive Auti, the results do not compare their interactions to their interactions with an actual animal. Some of our observations make it clear that at least some of the children were not classifying Auti as an animal: 10 of 18 children behaved differently toward the sleeping dog (which they initially thought was alive) than they did toward the Interactive Auti. Considering the difficulties children with ASD have generalising, it is not safe to assume that they are making links between Auti and animals. All that can be said is that children interact differently with the Interactive Auti and it is closer to animals than Active Auti is.

It was noticed, that children with different levels of functioning appeared to play with the toys differently: low functioning children explored the toys sensorily – touching it to their faces, feeling the vibration of the motors and holding the smooth legs while they moved – but did not engage with the action-response interactions. Those in the mid range, tended to interact with the action-response interactions, but their interactions often became repetitive. The higher functioning range moved more easily into extended play, pretending to feed the toy, or building houses for it. However, many did struggle with coming up with ideas as to what to do. These observations would fit with the cognitive theories of ASD.

This study found that 61% of children displayed identical behaviours or expectations with the sleeping dog as they did with Interactive Auti. This may indicate that some children were able to generalise the skills they learned from Auti. For some this was more clearly the case since they verbalized their expectations: "Why won't this one do the same thing?" However, some children may have been generalising the instructor's expectations for play which they had learned when Auti was demonstrated. This would indicate that they were generalising skills learned from the instructor rather than from Auti, which is an important distinction.

The lack of a face was also commented on by the parents and may have impacted both the extended play and the categorization of the toy. Three parents felt that no face was positive, one commenting that the no face meant that the toy didn't 'invade' her child's space. Six parents felt that no face resulted in their children not knowing how to interact with the toy. The rest of the parents thought it was fine either way, though all parents liked the idea of the face being an optional attachment like Mr. Potato Head. The thinking in the original design had been that less preconceived associations with Auti would make it easier to play with Auti in any manner. But it may be that associations that help inform children how to play with the toy would make it easier to engage with the toy particularly at initial stages. An experiment looking at how a face impacted the categorization of the toy and the extended play would be beneficial.

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