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
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.
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 discourage problematic behaviours (See Autity.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>
<thead>
<tr>
<th>Table 1. Group differences</th>
<th>Int. µ</th>
<th>Int.σ</th>
<th>Act. µ</th>
<th>Act.σ</th>
<th>Sig.</th>
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<td>90.00</td>
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<tr>
<td>PPVT</td>
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<td>89.60</td>
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<tr>
<td>AGE</td>
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<td>1.25</td>
<td>6.50</td>
<td>1.23</td>
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</tr>
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<td>WP</td>
<td>50.78</td>
<td>57.08</td>
<td>58.44</td>
<td>50.30</td>
<td>.77</td>
</tr>
</tbody>
</table>

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 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
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

<table>
<thead>
<tr>
<th></th>
<th>Int. $\mu$</th>
<th>Int.$\sigma$</th>
<th>Act.$\mu$</th>
<th>Act.$\sigma$</th>
<th>$X^2$</th>
<th>Sig.</th>
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<td>98.11</td>
<td>111.22</td>
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<tr>
<td>+physical</td>
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<td>0</td>
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<td>-</td>
</tr>
<tr>
<td>-total</td>
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<td>4.67</td>
<td>8.27</td>
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<td>.73</td>
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<tr>
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<tr>
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<td>2.42</td>
<td>16.64</td>
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### Table 3. Within-subject means and test statistics

<table>
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<tr>
<th></th>
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<th>Int.$\sigma$</th>
<th>Act.$\mu$</th>
<th>Act.$\sigma$</th>
<th>$t$</th>
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<tr>
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<td>.44</td>
<td>8.40</td>
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<td>.18</td>
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<tr>
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<td>15.80</td>
<td>1.44</td>
<td>2.24</td>
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<tr>
<td>Extension</td>
<td>3.33</td>
<td>3.91</td>
<td>1.89</td>
<td>2.42</td>
<td>1.13</td>
<td>.29</td>
</tr>
</tbody>
</table>

### 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.

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.

4. REFERENCES