A Study Of Auti:
A Socially Assistive Robotic Toy

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Abstract

This thesis is an evaluation of Auti, a new socially assistive robot designed by the author for children with autism. The study investigates whether Auti is effective at encouraging positive play interactions and reducing challenging play interactions through the application of Applied Behaviour Analysis principles. The toy aims to encourage positive play behaviours, such as gentle speaking and touching, using positive reinforcement by responding with movement. It aims to discourage challenging behaviours, such as screaming or hitting, through the removal of the reinforcing movements. The study evaluates the design by comparing how children with ASD play with a fully-interactive Auti to how they play with an active-only version which does the same movements but does not respond to the child. The study also looks at how children classify the toy and whether there is any indication that the skills they learn with Auti will be generalized to other areas. Results from 18 matched participants with confirmed ASD diagnoses indicate that the Interactive Auti does encourage positive behaviours more than the Active-only version, thus showing that it can be an effective medium for applying ABA principles of reinforcement. However, further design and research is needed around addressing challenging behaviours and increasing the range of the children’s behavioural responses.
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Autism spectrum disorder (ASD) is a lifelong developmental disorder with a behavioural definition. Individuals present with deficits in social interaction, impaired communication, and repetitive and restrictive behaviours and interests (American Psychiatric Association, 2013). Individuals vary in severity and presentation of these impairments, which will place them in higher or lower functioning sections of the spectrum. Some children are completely non-verbal, while others may have no language impairment. Other children cannot cope with even slight changes in routine, while some are fine with spontaneous change. Because the spectrum covers such a range of severity in many different combinations, the presentation of the disorder is remarkably heterogeneous, particularly now that the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) includes Asperger’s syndrome and Persuasive Developmental Disorder as a part of the ASD diagnosis (American Psychiatric Association, 2013). Raising children with ASD, though an enriching experience, also puts considerable financial, emotional and social strains on families. Montes and Cianca (2014) estimate that raising a child with ASD costs at least double that of a typically developing child and it can be significantly more depending on the severity of the presentation. Childcare, schooling and therapies can require significant resources with one parent often having to opt to become a full-time caregiver. Parents’ emotional and psychological quality of life is often affected.

Theories of Autism
As of yet, the etiology of ASD is unclear. Due to the heterogeneous nature of the disorder, it is likely to reflect multiple etiologies, which result in similar behavioural presentations. Not surprisingly, there are multiple approaches seeking to explain the disorder from various research perspectives, ranging from genetic and neurobiological approaches to cognitive and social theories.

There is strong evidence for a genetic component to ASD. High heritability has been supported by twin studies, results showing heritability as high as .9 for the wider spectrum and .7 for autism. The closer the heritability estimate is to 1 the higher the correlation is with genetic factors (Folstein & Rutter, 1977; Geschwind, 2009). Though some more recent studies showed lower rates,
Veenstra-vanderweele and Blakely (2012) argued that this could be indicative of an increasing number of diagnoses and changes in the diagnosis criteria. Family studies also support high heritability rates: with some finding a child with an autistic sibling is 25 times more likely to also have an autism diagnosis (Abrahams & Geschwind, 2008; Jorde et al., 1991). ASD is also often found to be more prevalent in individuals with other genetic disorders, such as Fragile X, Cowden, and tuberous sclerosis, than in the general population. This further indicates genetic variation as a major factor in ASD (Geschwind, 2009; Peça & Feng, 2012). Presently, there are more than 100 genes identified as being associated with ASD; but as yet, it is unclear how they interact to result in the disorder. It seems that a range of different genetic combinations can result in the ASD phenotype – from simple recessive genotype characteristics to complex interactions of multiple genes (Geschwind, 2009). Geschwind (2009) argues that multiple genetic variations can result in the autism phenotype as the phenotype itself is highly variable and behaviourally based. The functional overlap of genes may explain why so many variations can result in ASD (Peça & Feng, 2012).

Although making a significant contribution to the development of ASD, genetics are not sufficient, in and of themselves, to account for the disorder. The role of pre-natal environmental factors is still unclear. Higher rates of autism have been found in pregnancies with complications – though no single complication is clearly associated with ASD. Complications in the first trimester appear to be more strongly linked, particularly rubella and exposure to thalidomide and serotonin reuptake inhibitors (Veenstra-vanderweele & Blakely, 2012). High rates of autism have also been found when the paternal or maternal age is higher (Durkin et al., 2008; Hultman, Sandin, Levine, Lichtenstein, & Reichenberg, 2011). High testosterone levels during pregnancy are also being investigated as autism and extreme male tendencies are possibly linked (Klin, 2009).

Neurobiological findings may also explain some aspects of autism. Structural differences have been found between the autistic brain and typically developing brains. A higher incidence of post-natal overgrowth in the brain has been found among those with autism, appearing to be most prominent in the frontal lobes, the anterior temporal regions and connected parietal areas. These areas are associated with cognitive functions such as language, social cognition and executive function, which are key areas of impairment for children with autism (Courchesne et al., 2007; Courchesne, Carper, & Akshoomoff, 2003). These areas also contain the mirror neuron system which is strongly associated with empathy, imitation, and theory of mind which will be discussed in greater detail later. Abnormalities in the structures of white matter have also been identified. Short-range white matter connections appear overgrown while long-range connection growth is reduced. These irregularities could explain difficulties with generalization along with increased local processing abilities resulting in repetitive behaviours and narrow interests (Baron-Cohen & Belmonte, 2005; Courchesne...
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Theory of Mind is, simply put, the ability to attribute mental states to others (Premack & Woodruff, 1978). In autism, it is thought this ability is absent, or delayed (Baron-Cohen, Leslie, & Frith, 1985; Perner, Frith, Leslie, & Leekam, 1989). ToM deficit provides an explanation for the social and representational difficulties seen in individuals with autism, along with some of their communication difficulties. Individuals who lack an understanding that people have different mental states will necessarily have a very different way of relating, interacting and communicating with people. Traditionally, this ability has been tested through false belief tasks involving a scenario where a viewer knows something that the character within the scenario does not know (Baron-Cohen et al., 1985; Perner et al., 1989). To pass the task, the viewer must answer from the perspective of the character rather than the viewer. It has been found that many of those with autism struggle to pass (Baron-Cohen et al., 1985). However, 20% of the autistic population are, in fact, able to pass false belief tests which has led to further research into more complex ToM tasks. These tasks include second-order false belief tasks developed by Baron-Cohen (1989), which require a more complex representational theory of mind. Here the participant must reason not only about what another is thinking, but about what the other thinks a third person is thinking. Though this accounts for a larger percentage of the ToM deficit found in the ASD population, some higher functioning and older individuals are still able to pass the test. Baron-Cohen (1989) suggested that variation of abilities in the ASD population may be due to a delay in

et al., 2007). Similarly, abnormalities in the amygdala may explain emotion regulation difficulties (Aylward et al., 1999; Dalton et al., 2005); and abnormal brainstem growth and volume could explain sensory over- and under-reactivity (Jou, Frazier, Keshavan, Minshew, & Hardan, 2013).

Although all three of these diagnostic areas of autism can be linked to structural abnormalities found in the autistic brain, there are two major difficulties with all the studies. Firstly, none of the abnormalities occur in all cases of autism, and secondly, the abnormalities can occur without the presence of autism. Therefore, in spite of clear links between the brain structures and autistic behaviours, as well as the higher incidence of abnormalities in the autistic population, the relationship between abnormal brain structures and autism is controversial.

Cognitive theories consider possible cognitive mechanisms that would account for the behavioural symptoms of autism. Research has focused on three major theories: Theory of Mind (ToM), executive dysfunction, and Weak Central Coherence (WCC) theory. Some of these theories have clear links with the neurobiological findings above; for example, the overgrowth of short-range white matter fits well with Weak Central Coherence theory, and frontal lobe abnormalities are strongly associated with the theories of executive dysfunction and ToM difficulties.
Executive Dysfunction is a theory that covers a broader range of functions than theory of mind and postulates that autism is the result of deficits in executive functions. The theory arose from observations of behavioural similarities between those with autism and those with prefrontal cortex damage (Ozonoff, Pennington, & Rogers, 1991). Executive functions include initiating, sustaining, sifting attention, planning and inhibition (Denckla, 1996). Deficits in these functions could account for some of the difficulties individuals with autism face in switching attention, changing routines, and controlling impulses.

Executive functions are a range of functions associated with the ‘management’ of cognitive processes. Although it is not yet known how these processes interact, it is helpful to group them into narrower areas (Baddeley, 1996; Fournier, Larigauderie, & Gaonac’h, 2004). Burgess, Alderman, Evans, Emslie, and Wilson (1998) in their analysis of executive dysfunction tests conducted a factor analysis which categorized the functions into three areas: inhibition, intentionality, and executive memory. Inhibition describes difficulties with suppressing habitual responses. Intentionality includes functions related to initiating and maintaining goal-related behaviours. Executive memory collates functions related to confabulation, difficulties recalling orderings and applying changing rules. Those with autism have been
found to have difficulties in all three areas. However, such difficulties are not found across the whole autistic population (Pellicano, Maybery, & Durkin, 2005) and the levels and profiles of executive function deficits are not consistent even in those who do have such deficits (Hill, 2004). Nor do all individuals with ASD have deficits in the behavioural domains that executive functions underlie. Also, executive function deficits are not unique to autism – those with ADHD and OCD have similar difficulties – indicating that it cannot be the only pathology involved in autism.

It is also worth noting that there are inter-relationships between theory of mind and executive dysfunction. For example, difficulties with false belief tasks can be explained either by theory of mind deficits or by deficits in inhibition since the individual is required to inhibit their first response to where the item actually is (Russell, Mauthner, Sharpe, & Tidswell, 1991). An alternative theory – Cognitive Complexity and Control theory (CCC) – posits that ToM and EF difficulties are caused by an alternate single mechanism that underlies both cognitive functions. This theory argues that autism is the result of difficulties with higher order rules, and that the two other theories are consequences of the single problem, rather than competing explanations (Frye, Zelazo, & Burack, 1998; Zelazo & Frye, 1998).

Weak Central Coherence Theory (WCC) describes cognitive processing in terms of domain general and domain specific levels. The idea is that typically developing (TD) individuals give greater weight to domain general processing, being more likely to look at the ‘overall’ situation. Frith and Happé (1994) conjectured that those with autism have the opposite weighting, putting the cognitive priority on domain specific tasks thus comprehending each of the components separately rather than as a whole. Unlike EF and ToM deficit theories, WCC offers explanations for the non-social aspects of ASD such as the repetitive and restrictive behaviours and interests. Although the theory initially attempted to offer an explanation for all the behaviours, WCC is now considered to sit adjacent to deficits in social cognition (Happé & Frith, 2006). Domain specific processing would help to explain the savant characteristics associated with some individuals with autism, such as perfect pitch or mathematic abilities, as well as repetitive behaviours, restrictive interest, sensory abnormalities, and reduced generalization. Domain specific processing will bring the focus to every individual occurrence or pattern. So for things like repeatedly unscrewing a bottle top, each experience may be significantly different due to what may seem insignificant or unnoticeable changes. If those with ASD have difficulty grouping information, they may be encoding each instance separately rather than fitting them to a standard example, which would explain difficulties with reduced generalization and why they appear to notice the differences between things more than the similarities (Happé & Frith, 2006; Klinger & Dawson, 2001). In tasks to assess WCC, those with autism perform significantly faster at spotting and reproducing details (Shah & Frith, 1983, 1993), and slower at tasks...
that require generalization or context-related skills (Happé & Frith, 2006). However, as well as not offering an explanation for the social deficits found with autism, WCC is not demonstrated across the whole autistic population; and, thus, the theory does not provide universal explanation for those with the disorder.

Social motivation theory is an alternative kind of explanation to the cognitive theories. In both social motivation and cognitive theories, cognitive deficits result in social disruptions. But in the social motivation model, the cognitive deficits are not the root cause, but are themselves a result of lack of social motivation (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012). Humans are a socially-motivated species: we attend more to social stimuli; we are intrinsically motivated toward social interactions; and we seek to maintain social relationships (Chevallier et al., 2012). The theory argues that those with autism lack social motivation and in turn do not engage in social behaviours. Thus, they do not activate the relevant neurological and development processes; and, therefore, they experience developmental delays. However, like ToM deficits, social motivation does not offer an explanation for repetitive and restricted behaviours.

Treatments of Autism

The number of theories of autism and the disorder’s heterogeneous nature make it likely that multiple etiologies are in play and a single theory is unlikely to be uncovered. As more research is done, the profile of the factors involved in ASD will become clearer and hopefully lead to clearer paths in addressing the disorder. At present there are many treatments directed towards ASD with varying effectiveness. A survey in 2006 identified 111 different autism treatments (Green et al., 2006). Treatments and therapies range from medications addressing symptoms, to specific diets, to behavioural interventions. Some approaches try to address sensory abnormalities, either acclimating children to the stimuli such as Auditory Integration Training (Tharpe, 1999) or Sensory Integration Therapy (Lang et al., 2012) or by reducing aversive stimuli in the attempt to allow other functioning to develop without hindrance such as Scotopic Sensitivity Training (Ludlow, Wilkins, & Heaton, 2006). Some treatments focus on structure and exercise to help curb pathological behaviours, such as Daily Life Therapy (Quill, Gurry, & Larkin, 1989). Many treatments focus on communication, such as Facilitated Communication (Rosemary G Kerrin & Jones, 1998), The Picture Exchange System (Preston & Carter, 2009), and Speech Therapies. Others focus on bonding such as The Option Method (Jordan & Powell, 1993), Holding Therapy (Welch & Chaput, 1988), and Gentle Teaching (Jones & McCaughey, 1992; McGee, 1992). Others are skill focussed, such as Applied Behaviour Analysis (Axelrod, McElrath, & Wine, 2012; Lovaas, 1987) and Social Stories
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of psychology and is, in essence, the application of operant conditioning (Dillenburger & Keenan, 2009). Baer, Wolf, and Risley (1968) described ABA as the “direct application of behaviourism to the improvement of human behaviour” (p. 1). Over the years, ABA has been used and found effective across a variety of situations and over a range of conditions other than autism (Axelrod et al., 2012).

When applying ABA to a case of autism, the behaviours of the child are analysed to identify areas where the child is struggling. Specific goals are then set to help improve the aspects of behaviour that the child has difficulty with. This can range from increasing vocabulary, to toilet training, to the reduction of aggressive and self-stimulatory behaviours (Lovaas, 1987). After the goals are set, the therapists will identify appropriate rewards for the child and present these to help shape the behaviour. As behaviours change (or not), the goals and focus adapt to the child’s progress. Rewards are withheld when behaviours detrimental to the goals occur. Discrete trial training is an important aspect of ABA applied to autism. Here the child is given a cue, such as ‘pick up’, and a prompt to produce a desired behaviour. If the child responds, the reward is offered; thus reinforcing the desired behaviours. If the prompt is disregarded then the child is taken through the behaviour using methods such as “hand over hand” (Smith, 2001). The effectiveness of ABA has been found to be greater the younger the child is at intake, the higher the intensity (the number of hours per week), the longer the duration of the treatment, and

(Karkhaneh et al., 2010; Test, Richter, Knight, & Fred Spooner, 2011). Music therapy is also commonly used (Reschke-Hernández, 2011). Some treatments such as TEACCH are eclectic using a range of techniques from multiple approaches (Ichikawa et al., 2013; Mesibov & Shea, 2010).

Many autism treatments are controversial and not supported by experimental evidence. The majority of treatments rely on parental reports and one-off studies. When experimental studies are done, the majority of them show little or no difference between the experimental and control groups (Howlin, 1997). In many cases, it is argued that improvements are not due to the therapies but due to the increased one-on-one time spent with the children. Unfortunately, given the lack of an evidence-based unifying theory, and the variability in the presentation of the disorder, it is not yet possible for treatments to be precisely targeted at the disorder resulting in many of the attempted treatments being ineffective. However, among the myriad of treatments, behavioural-based interventions have been shown to be the most promising and effective, and have been the focus of much research since the 1970’s.

Applied Behaviour Analysis (ABA) in particular is the most researched of the autism treatments, with 40 years of development (Keenan & Dillenburger, 2011; Rogers & Vismara, 2008; Walsh, 2011), and it is considered to be the most effective (Matson et al., 2012). ABA is an approach to therapy arising out of the behaviourist perspective
the more the parents have been trained (Makrygianni & Reed, 2010).

There have been multiple rigorous reviews that have addressed ABA and autism (Axelrod et al., 2012; Larsson, 2005; Makrygianni & Reed, 2010; Matson, 2007; Matson et al., 2012; Rogers & Vismara, 2008) demonstrating a consensus that ABA is an effective intervention for behavioural aspects of autism. It has also been shown that ABA is more effective than eclectic treatments, see (Makrygianni & Reed, 2010; Zachor, Ben-Itzchak, Rabinovich, & Lahat, 2007). Lovaas’ 1987 seminal study showed significant improvement from ABA interventions with 47% of the 19 participants acquiring almost ‘normal functioning’. Although the generalizability of this sample is questioned and subsequent studies have not shown as high numbers, there is still a consensus that it is an effective treatment. Participants show significant improvements in IQ, language, and a reduction in pathological behaviours (Keenan & Dillenburger, 2011; Lovaas, 1987; Rogers & Vismara, 2008).

To varying degrees, the extant evidence base is limited by a range of methodological issues. These include restricted sample sizes, variability in selection, randomization, insufficient matching with control groups, and problematic measures used to assess functioning. The research base is challenged for lacking demonstrations of efficacy established using a randomly controlled trial (RCT) approach. However, Keenan & Dillenburger (2011) argue that this criticism itself is flawed and that RCT’s are not in fact the best way to test the effectiveness of ABA, partly because of the great variability in the application of ABA to each individual. Nonetheless, ABA is still the most evidence-based treatment and has become a requirement for insurance providers in many US states (National Conference of State Legislatures, 2012). This thesis investigates an intervention that uses an ABA approach, delivered via a robotic toy.

Robots and Autism
The use of robotics in teaching children with autism is also a recent area of exploration. The emerging field of socially assistive robots investigates robots that help develop or aid social interactions for a range of users such as the elderly, stroke patients, and those with cognitive disorders (David Feil-Seifer & Mataric, 2005). It is important to investigate this area, as it may prove to offer a more economical and readily available way to assist those with autism. Existing therapies are both expensive, and often hard to get into with some areas dealing with large wait lists (Howlin, 1997). ABA is considered most effective at an intensity of 40 hours a week, making it unaffordable for many people. Robotics, though not able to replace the role of a therapist, may be able to extend teaching beyond their presence, reinforcing their work and reducing over all cost.

Socially assistive robots are particularly interesting for teaching those with ASD as robots may offer an intermediate step between inanimate objects and people.
Having an intermediate step may help the child learn social interactions because robots have a mixture of characteristics of inanimate objects and human agents. There are two reasons why this mixture of characteristics within robots maybe helpful. Firstly, they allow some elements of social interaction without confusing the child with an overwhelming onslaught of social stimuli. Secondly, pairing the social stimuli with stimuli which are already attractive to the child draws more overall attention (Sasson & Touchstone, 2013).

As mentioned when discussing social motivation theory, children with ASD tend to show a preference for interacting with inanimate objects over people (Celani, 2002; Stanton, Kahn, Severson, Ruckert, & Gill, 2008). Further, Diehl, Schmitt, Villano, & Crowell’s (2011) analysis of the current research found that the current studies indicate that at least initially, agents with robotic characteristics are preferred over both passive toys and humans. They also suggest that robots could be effective in eliciting behaviours although the research reviewed was predominantly theoretical. Interestingly, Diehl et al. (2011) only found one robot (Duquette, Michaud, & Mercier, 2008) which provided positive feedback based on performance, 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. (For more reviews see Michaud & Théberge-Turmel, 2002; Scassellati, Admoni, & Mataric, 2012).

Although evidence for robots to be used as a successful medium for teaching children with ASD is building (Frances & Mishra, 2009; Francois, Powell, & Dautenhahn, 2009; Kim et al., 2012; Kozima, Nakagawa, & Yasuda, 2007; Michaud & Caron, 2002; Stanton et al., 2008), the research is still new and has limitations. Many autism researchers have difficulty in finding participants. The studies in robotics have particularly low participant numbers, typically between 1 and 5. Also, as Scassellati, Admoni, and Mataric (2012) point out, much of the robotic research is from an engineering perspective which has different priorities and methods. This means the majority of the studies are characterised by having few or no human controls, no qualifying diagnostic tests for the participants, and are focused only on the robots’ performance rather than the children’s. There is clearly a need for more careful studies from a psychology perspective in this area.

It is useful to split robotics into three types: humanoid, anthropomorphic/zoomorphic, and moving non-representational robots. Humanoid robots tend to be used for eliciting imitation, teaching facial expressions and learning human interaction. For example, Pierno, Mari, Lusher, and Castiello (2008) found that children with autism were better at imitating a robotic arm demonstrating a task than a human one. Significant robots in this category include Bandit (D. Feil-Seifer & Mataric, 2008), Kasper (Cheng, Lin, & Huang, 2013) and Nao (Hashim et al., 2013; Miskam et al., 2013). Anthropomorphic/Zoomorphic robots tend to be used
for capturing attention, and promoting a larger range of interactions, such as joint attention (Kozima, Michalowski, & Nakagawa, 2009), rather than replicating interactions. Significant robots in this category include AIBO, the Sony dog (Francois et al., 2009, 2009; Kahn, Friedman, Perez-Granados, & Freier, 2004; Stanton et al., 2008), My Keepon (Kozima et al., 2009, 2007; Scassellati et al., 2012), and Pleo (Kim et al., 2012). Non-representational robots are less common in autism research as their use is mainly for attracting attention and engaging the user. Roball (Michaud & Caron, 2002) was an early robot in this category which is commonly cited. Though the form of Roball was just a ball, its movements had anthropomorphic qualities that allowed children to attribute it with social characteristics.

The research in this thesis uses Auti, a robot designed and created by the author. Auti is a socially assistive, robotic toy, belonging to the anthropomorphic/zoomorphic category, designed to help encourage positive play behaviours and discourage problematic behaviours (see Figure 1). Auti employs ABA principles, applying reinforcement through movements when positive play behaviours like talking, patting and initiation occur and removing reinforcement by shutting down and not responding when challenging behaviours like screaming, hitting and 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 (Nittono, Fukushima, Yano, & Moriya, 2012). 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 in movements which combine up-down and in-out motions. The limbs are controlled by independent servos which give the toy a large range of possible movements. It can detect two 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. Rough interaction with the toy is detected with an accelerometer. If the acceleration threshold is exceeded, the toy stops and cannot be reactivated for 5 seconds.

Figure 1. Auti – A Socially Assistive Robotic Toy.
Auti responds to gentle touching with one of three responses: it either quickly lifts its body up twice in attention, or it puts all of its limbs out and lowers itself slowly to the ground, or it does a 'sideways push-up' by putting its left limbs out and lifting its body twice quickly with its right limbs (See Figure 2 and Video Appendix 1).

Auti also responds to sound, distinguishing gentle talking from shouting or screaming. When spoken to, Auti responds with one of three further responses: it either ‘waves’ by tilting back and waving its front right limb; or it ‘runs on the spot’ – quickly moving its limbs up and down with the movement alternating between diagonally opposing limbs; or it ‘rocks from side to side’ where the right and left limbs alternately extend out to tilt the body (See Figure 3 and Video Appendix 1). In response to rough interactions or shouting, the toy freezes for 5 seconds.

At the end of every response (verbal or physical), Auti ‘walks on the spot’ – a slower version of ‘running on the spot’ (verbal response 2) – for 5 seconds. After it has finished walking, if it has not been interacted with, Auti ‘rests’. When 'resting ', Auti 'sits' putting its back limbs out and 'pawing' with it’s front limbs every 10 seconds.
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This is an alternating movement designed to be similar to the movements a pawing cat makes while settling down. The aim of this state is to encourage initiation – the little movements indicate that the toy is still responsive, but the child must initiate further interaction with touch or voice. If Auti is upside-down, it waggles its limbs gently until it is turned back over (see Figure 5).

Auti also has a remote control that an instructor can use. If a child is generally rough, the acceleration threshold can be increased or disabled using the remote. The remote is also used as a manual back-up to control Auti in the event that any sensor fails or the accelerometer is turned off. The remote also allows the instructor to control which of the responses would occur in response to each interaction. This allows the toy's behaviour to be adapted if a child shows a dislike for a particular movement.

This current study explores the effectiveness of applying reinforcement through the medium of Auti. The applications of operant conditioning through ABA programs have been seen to be effective in encouraging and discouraging behaviours, and children with ASD have

Figure 4. Resting

Figure 5. Upside-down
preferences for interacting with robots over humans and inanimate objects. Considering this, the current study hypothesized that children who played with the full Interactive version of Auti (the experimental condition) would display more targeted positive behaviours such as patting and talking and less targeted challenging behaviours like screaming and hitting than those who interacted with the modified Active version of Auti which does not employ operant techniques (i.e., Active Auti does not respond in a manner contingent on the nature of children’s interactions).

A second aim of the study was to see how children classified the toy when they interacted with it. Kahn et al. (2004) investigated how children with autism classified AIBO, the Sony dog, compared to a moving dog toy and a stuffed dog toy. They found that the children treated AIBO differently from the other two toys and displayed more socially-driven behaviours such as reciprocity and apprehension indicating that children were classifying the robot differently from standard toys. The classification of Auti is of interest to this study for two reasons. Firstly, it helps to indicate how the children might generalize the behaviours they learn with Auti; for example, whether they would generalize the behaviours to household animals or to their soft toys. Secondly, if children are reacting to the toy as if it is a live animal, then we may be able to expect some of the same outcomes found with Animal Assisted Therapy (AAT) and inform more focused directions for assistive robotic research. Nimer & Lundahl’s (2007) meta analysis not only shows clear evidence that AAT is an effective intervention but also notes that it has been consistently beneficial for young children, including in programs addressing behaviours associated with autism. There may also be similarities in how robots and animals can be used in therapy. Martin and Farnum (2002) suggest that one of the reasons AAT may be beneficial is that animals may act as a transitional object – initial bonds created with the animal can then be transferred to humans. In the same way that robots may act as an intermediate step for social interactions. Their study comparing ASD children’s behaviours with a real dog, a stuffed dog, and a ball found that problematic behaviours like hand flapping significantly decreased while social behaviours like verbal interactions increased. The increase of language use and social behaviours was also found by Sams, Fortney, and Willenbring (2006) when comparing occupational therapy alone with ATT. Theses results were similar to the results found by Stanton et al.’s (2008) study of children’s social behaviours in relation to AIBO. Based on these studies, the current study hypothesised that the children in the Interactive condition would use more anthropomorphic/zoomorphic language and display more social behavioural interactions than the children in the Active control condition.

It is also of interest whether any behaviours learned with Auti are generalized. As mentioned in the cognitive theories of autism, particularly in relation to WCC, children with autism struggle with generalization. In ABA, generalization skills are specifically targeted: behaviours are taught across settings or in increasingly unstructured
A Study of Auti

ways (Lovaas, Koegel, Simmons, & Long, 1973; Steege, Mace, Perry, & Longenecker, 2007; D. Tennov & Jacobson, 1977; Dorothy Tennov, Jacobson, & Vittucci, 1980). Auti only employs repetitive reinforcements for desired behaviours, most similar to the discrete trial training (DDT) in ABA. There is no evidence to believe that generalization would be more likely with the Interactive Auti than the Active one, as it does not use the techniques for teaching generalization. However, it is important to know if any skills are being generalized as this helps to determine the effectiveness of the toy. To evaluate this, after the children in both conditions have played with the interactive Auti, they are given a sleeping dog toy to play with and any generalized behaviours are recorded. This does not give any measure of how much generalization occurs or if generalisations occur more with Auti than other toys, but it does give an indication of whether or not the skills could be generalized and helps inform future research.
Method

Overview
The study was a mixed, experimental design delivered over 2 ½ – 3 hours 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 randomly allocated into one of two conditions. The first condition used the full Interactive Auti, which responds to a child’s behaviour as described above. The second (control) condition used Auti running an Active (but not Interactive) program. Active Auti ignores all sensors and does not respond to the child’s behaviours. Instead, it automatically cycles through its movements. At the end, children in the Active condition were given the Interactive Auti to see if there were any differences in their play behaviours – providing both between-subject and within-subject comparisons.

Participants
The participants consisted of 19 children between the ages of 4 years 6 months and 8 years 2 months with an autism diagnosis. Four of the participants were female and the rest were male. One participant was excluded, as they did not meet the ASD criteria for the study. The mean age of the Interactive group was 6 years 5 months (SD=1.25) and the mean age for the Active group was 6 years 6 months (SD=1.24). All participants had a formal autism diagnosis from a paediatrician, and this diagnosis was supported by scores from the Gilliam Autism Rating Scale Second Edition (GARS-2) ranging from 71 to 117 (scores below 69 are indicative of ASD being unlikely). Nine participants were assigned to the experimental condition and nine to the control condition. The participants were matched across the conditions according to their ages and their scores on the GARS-2 test, the Peabody Picture Vocabulary Test (PPVT), a test of receptive vocabulary, and on the Colour Progressive Matrices (CPM) test, which is a non-verbal test of reasoning ability. Means and standard deviations of the matching criteria in each group are presented in Table 1. If there were multiple matching possibilities then the pair with the most similar play temperaments were matched. The play behaviours of the groups were also checked by having the children first play with a Furreal Friends Walkin’ Puppy (Figure 6). This checked to see if one group showed a preference for moving fluffy toys over the other. The number of
interactions with the walking puppy were not statistically different between the groups (Table 1). Participants were recruited from around the North Island of New Zealand through Autism New Zealand, by word of mouth, and through notices on autism Facebook pages, as well as the AutiToy Facebook page. For their involvement participants received a miniature Auti soft toy.

**Apparatus**

Pre-experiment tasks. Before the experiment the children completed the Gilliam Autism Rating Scale Second Edition, the Peabody Picture Vocabulary Test and the Colour Progressive Matrices, along with an open-ended questionnaire which covered topics like the child's typical play behaviours, their exposure to toys and animals, and their home environment (see Appendix 1). Parents also signed consent forms (see Appendix 2).

**Toys.** Initially, the children interacted with a 'Furreal Friends Walkin' Puppy, which was modified to remove the all the puppy sounds as well as the 'pat switch' which turned the walking on. The result was a dog-shaped toy which would walk indefinitely when turned on (see Figure 6). At the end of the experiment the children interacted with a Perfect Petzzz® chocolate lab (see Figure 7) which is a realistic sleeping puppy. It was provided in the interest of seeing whether any of the behaviours exhibited

<table>
<thead>
<tr>
<th></th>
<th>Condition</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>t-test p value</th>
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<td><strong>GARS-2</strong></td>
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<td>15.35</td>
<td>.91</td>
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<tr>
<td></td>
<td>Active</td>
<td>90.00</td>
<td>16.03</td>
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<td>34.86</td>
<td>.70</td>
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<td></td>
<td>Active</td>
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<td>13.82</td>
<td>.86</td>
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<td></td>
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<td>14.61</td>
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<tr>
<td><strong>AGE</strong></td>
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<td>.92</td>
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<td>1.23</td>
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<td>57.08</td>
<td>.91</td>
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<tr>
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<td></td>
<td>Active</td>
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towards Auti were generalized to the sleeping dog. The children were also given support toys for Auti. These included a brush, a sheepskin and blocks. These were provided to elicit extended or imaginative play.

**Auti.** This study used two versions of the Auti toy, one with an 'Interactive' program and one with an 'Active' program. When executing the Interactive program, the toy responds to interactions as described above. However 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. When executing the Active program, Auti cycles through its movements randomly so that no distinguishable pattern can be predicted. In order to ensure that Active Auti performed the different movements in the same proportions as during play with Interactive Auti, the probabilities of each movement in the Active program were weighted to occur with the same frequency on average as during Interactive play. Movements were randomly selected from 12 movement options. The 'walking on the spot' movement was weighted most heavily being picked one quarter of the time as walking occurs most frequently in normal Interactive play. The 'sitting and resting state' occurred 1/6th of the time. The remainder of the movements were all weighted to occur 1/12th of the time. The 'sitting and resting' state varied in duration as the child can leave the toy inactive for varying periods of time when with playing Interactive Auti. Active Auti simulated this variation by randomly altering the
length of the time between 15s to 30s. This time variation was also the case in the ‘wagging on back’ movement – the Active program randomly altered the length of the time between 4s and 13s.

The experiment was recorded from two angles using a GoPro Hero3 and a Sony Handycam.

**Procedure**

**Pre-interview.** The instructor (the author) conducted a 1 hour interview with parents and children. For some this was split into a half hour interview with parents followed by a half hour to 45 minute session with the child. The interview with the parent/s started with a verbal completion of the GARS-2 form, followed by an open-ended verbal questionnaire gathering general background information such as the child’s interactions with animals and typical play behaviours. The PPVT and CPM tasks were administered to the children. These initial sessions also gave the children an opportunity to become comfortable with the instructor in order reduce anxiety during the experimental interaction session. Although the aim was to do the pre-interview on a separate day from the main experiment, finding participants proved difficult and traveling became necessary. Due to more constrained scheduling, the pre-interviews and trials took place on the same day for some children. To account for fatigue in these cases, the children were given breaks between the pre-interview and the experiment. In several cases \((n = 3)\), the time was scheduled over lunchtime. The child did the initial tests and then had a break to eat and do a preferred play activity before starting the experiment. The parents were also interviewed after the child, giving the child more of a break.

**Main Experiment.** The trials took place in the child’s home to ensure that the children were in an environment where they felt comfortable, and this removed potential difficulties some children with ASD may otherwise have with adapting to new places. A home environment also best simulated the environment where the toy would most likely be used. To help minimise distractions, parents kept other siblings out of the room as much as possible. Video cameras were set up in the room from two angles and turned on before the toys were introduced. During the set up time, the children played with the blocks to distract them from the cameras and to allow them to get comfortable playing in the videoed area.

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 children were given permission to play with the walking puppy using phrasing such as, “Would you like to play with this?” or “Come look at this”. “This” was used rather than “this toy” or “this dog” so classification of the object was not influenced. If the child said “doggy” or equivalent, then the instructor followed suit. If the child did not engage, the instructor encouraged interaction through phrases such as:

“It’s ok to play with it.”
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 sheepskin and blocks were introduced and the instructor referred to Auti as a 'he' to see if this changed how the child classified the toy.

During play, the instructor followed child’s lead. If the child wanted the instructor to play too, then the instructor engaged enthusiastically. However, if the child’s attention was waning (a 5 minute period of frequent distraction), the instructor would suggest further play such as “What happens if you turn it upside down?”

If the child was timid, then after 15 seconds of the child not approaching the toy in any way, the instructor modelled behaviours and used phrases such as, “Look what it does when I pat it” or “Look what happens when I speak to it”. If the child became distracted, then after 15 seconds of not paying attention, the instructor redirected the child by saying: “What about this?”, “Remember this?”, “Why don’t you talk/pat/play with this?”, or the play was modelled by the instructor. In both these cases, parents also encouraged contact by modelling the play or verbally directing the child. In three cases, where the child showed no interest, the parent used “hand over hand” to show the child.
If the child showed confusion, or lost interest when a shutdown occurred, the shutdown was explained, and child’s attention redirected:

“It won’t work if you hit/throw/shout/scream at it.”

“You have to be very gentle when you play, otherwise it stops.”

“Why don’t you try patting/talking/hugging it again?”

If the child was in the control condition with the Active Auti, and they were timid, became distracted or confused then the instructor redirected attention but did not explain the toy’s movements or the use phrases such as “See what happens when...” as such statements wouldn’t make sense with the Active Auti.

After the last session of Auti-focused playtime, a realistic looking “sleeping dog” was placed near the child and Auti was taken away. If the child did not notice the dog, the instructor directed their attention towards the sleeping dog. If no action was made then the instructor gave them permission to pat the “dog”. The time with the dog lasted for 5 minutes.

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 during this interaction. At the end, the parents and children were debriefed and given the opportunity to ask questions.

**Coding**

The video recordings were coded for positive and negative physical and verbal interactions and their causes (own initiative vs. prompted by instructor), the time it took to approach the toys, how they classified the toys, and whether they engaged in extended play with the toy. Seven videos were coded by a second coder and a high correlation was found between the scores from each, \( r(151) = .99, p < .001 \).

**Positive physical contact.** If the child patted, caressed, held, physically explored, or gently touched the toy, it was counted as physical contact. One pat consisted of making contact with the toy and then releasing contact. This will cause the toy to respond, and can be very short. If a pat lasted a long time, such as continuously rubbing the fur, a new pat was counted every 2 seconds. Two seconds was set as it was a standard pat time – adequate time for a slow gentle pat or stroke. The 2-second rule was applied to all the types of physical interactions: a physical interaction equated to either the child touching and releasing the toy or maintaining contact with the toy for 2 seconds or more. The only time physical interactions were not counted was when they appeared accidental – this was when the child had no eye contact, no behaviour directed towards the toy and no reaction to the toy touching them.

**Negative physical contact.** If the child hit, threw, or forcibly restrained the toy, it was counted as negative contact. One hit or throw (making contact then releasing),
counted as one negative physical contact. If the child tried to restrain the toy by pushing down, sitting on it, or trying to forcibly move the toy’s limbs opposing the toy’s movement (note that this is different to exploring the toy by waggling the legs to see how they move), then every 2 seconds in the behaviour were counted as one negative physical interaction.

Positive verbal interaction. If the child made any verbalization directed at the toy, it was counted as a positive verbal interaction. To be directed at the toy, the child must be either looking at the toy, moving or have their face close to the toy, and there be no indication that attention was directed towards anyone or anything else in the room. A continuous verbalization and then a break counted as one positive verbal interaction. This could be short, like ‘hello’ or ‘boo’, or it could be a string of words or sounds, such as ‘Are you hungry?’. Every time there was a break in speech, a new interaction was counted. Only 2 children used more than single word or sound interactions.

Negative verbal interaction. If a child screamed or shouted at the toy, it was counted as a negative verbal interaction. For the interaction to be directed at the toy, there must be no indication that it was directed towards anyone or anything else in the room and the child must be either looking at the toy, or showing behaviours towards the toy matching the vocal out burst, i.e. pushing the toy away or hitting the toy, etc.

Initiation of the interactions. If the child physically or verbally interacted with the toy because they had been prompted by the instructor or a parent, then the interaction was coded as ‘other initiated’. Every interaction was checked to see its cause and to check if the child had just been redirected to the toy or if the behaviour had just been modelled.

Extended play. If a child went beyond the simple action and response play then it was counted as an ‘extended play’. Extended play was any play that incorporated more than simple interactions to get a response. These could include the child playing with Auti and other toys, such as the walking puppy or planes, or balancing blocks on Auti’s back and then talking so the blocks would fall off when Auti responded. An extended play was counted the first time a new play was seen or if the play had not occurred for 3 minutes.

‘Alive’ classification. If a child referred to the toy using anthropomorphic or zoomorphic language or their behaviours towards the toy were as if it were ‘alive’, it was counted as an ‘alive’ classification. If the child used words like ‘he’ or ‘she’, or attributed feelings or states like ‘It’s cold’ or ‘Will it like that?’, it was counted as an ‘alive’ classification. If they put it to bed, or dressed it up, helped it move, brushed its fur, or any behaviour that indicated they were treating it as an entity rather than an object, it counted as an ‘alive’ classification. Every instance counted as a separate classification. If a sentence was “Let’s feed it and put it to bed”, then it was counted as 2 classifications.
because there were two types of words classifying it. If they dressed it up more than once, it was counted on each occurrence.

**Generalization.** A child’s behaviour was counted as a generalization, if they used exactly the movements or words with the sleeping dog that they had used with Auti, or if they asked why it wasn’t doing the same thing as Auti, or if they asked if examiner could make it work like Auti.
Results

In all the analysis below, interactions that were initiated by the instructor or parent were not included and significance was set at an alpha level of .05. Initial inspection of the data revealed high variability between the children, and a high number of zero and low counts (see figures 8 and 9). One explanation was that the data did not fit a normal distribution, which is consistent with count data and with the data having such high standard deviations compared to the mean. In particular, the number of positive verbal interactions where the count was zero in the Active condition indicated that a distribution which accounted for high zero counts would better describe the expected distribution. Exploratory data analysis was carried out to see if results were normally distributed. Positive behaviours in the Active condition had a slight skewness of 1.48 (SE=0.72) and the skewness and kurtosis of the negative interactions in both the Interactive (skewness =2.21, SE=0.72, kurtosis = 5.02, SE=1.40) and Active (skewness =2.21, SE=0.72, kurtosis = 7.35, SE=1.40) conditions indicated non-normal distributions. The Kolmogorov-Smirnov normality test also indicated that the positive interactions in the Active condition (D = .31, p = .009) and negative interactions in the Interactive (D = .29, p = .032) and Active (D = .37, p = .009) conditions all significantly deviated from normal distributions. When broken down into the separate types of positive and negative interactions (verbal and nonverbal), the distributions still deviated from the normal. Histograms of the results suggested a Poisson distribution, which is a common distribution for counts. The results were therefore assessed with a Generalized Linear Model (McCullagh, 1984) using a Poisson regression with a log link function. This is a common alternative to t tests when the normal distribution is an unreasonable assumption and is most often used for analyzing count data. This analysis makes it possible to determine whether the difference in the observed counts in the two conditions is statistically significant. The Wald statistic (a particular form of a $X^2$ statistic) on the slope coefficient of the Generalised Linear Model is the appropriate measure for assessing the significance of the results. All $X^2$ in the results refer to that Wald statistic.
Figure 8. Box and whisker graph of the number of positive interactions in the Interactive condition, next to the number of positive interactions in the Active condition.
Figure 9. Box and whisker graph of the number of negative interactions in the Interactive condition, next to the number of negative interactions in the Active condition.
Positive Physical and Verbal Interactions Across the Two Groups

As the hypotheses predicted, the Generalized Linear Model showed that significantly more positive verbal and physical interactions, occurred in Interactive condition ($M=222.89$, $SD=151.68$) than in the Active condition ($M=98.11$, $SD=111.22$); $X^2 (1)= 412.84, p \leq .001$. 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 ($M=122.00$, $SD=94.22$) than they did when they played with the Active Auti ($M=40.67$, $SD=54.45$); $t(8)=3.77, p = .05$.

When the positive interactions are broken down into the verbal and physical interactions, the comparisons are still statistically significant. For the means, see Figure 10. Positive physical interactions occurred more in the Interactive condition ($M=197.33$, $SD=137.26$) than in the Active condition ($M=98.11$, $SD=111.22$); $X^2 (1)= 287.99, p \leq .001$. Verbal interactions were greater in the Interactive condition ($M=25.56$, $SD=36.23$) as they did not occur at all in the Active condition.

Again children who played with both toys displayed significantly more positive physical interactions in the Interactive ($M=108.89$, $SD=87.32$) than the Active ($M=40.67$, $SD=54.45$) condition; $t(8)=-23.35, p = .01$, and significantly more positive verbal interactions in the Interactive ($M=13.11$, $SD=13.46$) than the Active ($M=0.00$, $SD=0.00$ condition; $t(8)=-2.92, p = .02$.

Figure 10. Mean Number of Positive Interactions in the Active and Interactive Conditions.
There was no significant difference found between the number of positive physical interactions with the walking puppy ($M=50.22, SD=56.98$) and the Interactive Auti ($M=85.78, SD=78.05$) condition; $t(8)=-0.94, p = 0.38$. Nor was there any significant difference between the number of positive verbal interactions with the walking puppy ($M=58.44, SD=50.30$) and the Active Auti ($M=40.67, SD=54.45$) condition; $t(8)=1.14, p = 0.29$.

61% of children’s behaviour indicated that skills were generalised from Interactive Auti to the sleeping puppy.

**Negative Physical and Verbal Interactions Across the Two Groups**

There was no significant difference between the number of negative interactions displayed in the Interactive condition ($M=4.33, SD=7.67$) and the Active condition ($M=4.67, SD=8.27$); $X^2(1)= .11, p ≤ 0.73$. Nor when the physical and verbal interactions were analysed separately were any significant results found. (See figure 11) This was also the same for the negative interactions displayed by the children who played with both the Interactive ($M=0.22, SD=0.44$) and the Active Auti ($M=44, SD=8.40$); $t(8)=1.48, p = .18$.

![Figure 11](image-url)
Classification of Auti Across the Groups

A significant difference was found between the number of times the children categorised the Auti as ‘animal like’ in the Interactive ($M=8.56$, $SD=11.00$) and the Active ($M=1.44$, $SD=2.24$) conditions: $X^2(1)= 35.19$, $p \leq .001$, with more occurrences in the Interactive condition (See figure 12). There were, however, no significant differences in the number of times the children who played with both Auti’s classified it as animal-like in the Interactive ($M=7.22$, $SD=15.80$) and the Active ($M=1.44$, $SD=2.24$) conditions, $t(8)=1.06$, $p = 0.32$.

Extended Play Occurrences Across the Groups

Instances of extended play occurred significantly more in the Interactive ($M=5.89$, $SD=2.858$) than the Active ($M=1.89$, $SD=2.42$) condition; $X^2(1)= 16.64$, $p \leq .001$. (See figure 12) There were however no significant differences in the number of times the children who played with both Auti’s extended their play in the Interactive ($M=3.33$, $SD=3.91$) and the Active ($M=1.89$, $SD=2.42$) conditions, $t(8)=1.13$, $p = 0.29$.

Figure 12. Mean Number of Classification and Extended Play Occurrences in the Active and Interactive Conditions.
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 play can be encouraged through a robotic toy. The gathered data had high variability; this, however, 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. For example, children who are non-verbal will interact differently to those who have no language delay. More subtle differences such as variations in ToM abilities or different executive function profiles may alter play behaviours in unknown ways. Higher levels of ToM ability have been linked to imaginative play abilities (Astington & Jenkins, 1995; Taylor & Carlson, 1997). Rutherford and Rogers (2003) found that “generativity” aspects of executive functions, which would come under Burgess et al.’s (1998) intentionality category of EF, are predictive of pretend play abilities. It is likely that some of these differences account for the high variability of the results. In addition, the range of ages and abilities within the groups varied from four and a half to just under eight years, and from non-verbal, low-functioning to high-functioning. So, in spite of the groups being well matched, the variation between individuals within the groups would affect the variability of the results.

Positive behaviours. As this study hypothesized, the children in the Interactive conditions displayed significantly more targeted positive behaviours than in the Active conditions. 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 through 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 tell us that responsive movements of a robotic toy are enough of a reward compared to non-responsive movements to encourage positive interactions. Considering Diehl et al.’s (2011) point about the lack of research and development around robotics incorporating ABA principles this finding is important, not just for Auti but for all such robotic toys. It is known that children with ASD show a preference for robotic interactions, but the types of robotic movements vary and there have not been studies as to the effectiveness of different types of movements. Some robots have very mechanical predictable movements while others, like Auti, have movements which are more natural and human-like. This experiment is important because it showed that responsiveness is an important factor. Further research on the impact of this factor would be beneficial to designing engaging interactions.
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 the Interactive Auti after the Active Auti also displayed significantly more positive interactions with the Interactive version. It would be interesting to see whether within-subject experiments which controlled for order effects had the same results.

There were limitations to the interactions displayed by the children. Of the positive verbal interactions, ten of the 18 children (note, four were non-verbal so used no language) interacted only using the word ‘hello’, which was the word the instructor used to demonstrate the interaction. Similarly, physical interactions, which were also significantly higher in the Interactive condition, had limitations. Once the child had found a consistent way of activating Auti’s physical interaction response, seven of them just repeated the interaction over and over.

The analysis part of ABA is crucial to its effectiveness in addressing an individual child’s behaviours (Pierce & Epling, 1980). Currently, no robots, including Auti, are able to analyse and address behaviours. 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 the robot can distinguish or sense, the more behaviours it can be programmed to target. It is possible that the varieties of interactions could be increased, if Auti could distinguish more finely between different types of positive interactions. With voice recognition, different phrases could be targeted and, with more refined sensors, different types of patting or cuddling could be distinguished and responded to differently. However, it may be important to determine whether the children are able to differentiate between Auti’s different movement responses. Further research and development into this area would be interesting.

Intriguingly, there was not a significant difference between the number of positive interactions with the walking puppy and Auti. However, there was one extreme outlier, which indicates something interesting. One participant had 187 positive interactions with the walking puppy and only 5 with the Interactive Auti. This participant showed a preference for the dog, asking to play with it in the self-directed play times and showing distress when the toy was taken away. Conversely, he showed very little interest in Auti and had to have his attention constantly redirected. Without this outlier, there were significantly more positive interactions with Interactive Auti ($M=103.38$, $SD=76.5$) than with the walking puppy ($M=33.75$, $SD=27.22$), $t(7)=2.39$, $p = .05$, which aligns with the other results. Considering the low sample size, it would be unjustified to remove the outlier, as it is likely that others would display similar behaviours. However, this outlier does illustrate that preference for the toy is extremely important. If the child does not prefer the toy, the toy’s movements would not be perceived as a reward and one could not expect them to have any effect on behaviour. To apply this insight to Auti, it would need to be highly customisable able to effectively
engage with a wide range of children, particularly because sensory preferences and abnormalities of ASD children are extremely varied and often extreme (Leekam, Nieto, Libby, Wing, & Gould, 2007; Rogers & Ozonoff, 2005). Further research exploring how effective reinforcement using a robot for which a child has already demonstrated a preference, would also be worthwhile.

**Challenging behaviours.** 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. Moreover, since challenging behaviours seldom occurred, they had little opportunity to learn the pattern of the toy’s responses. Although in the pre-interview, most parents reported issues with challenging behaviours (n= 15), very few children displayed these behaviour during the experiment. 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 behaviours (Matson & Nebel-Schwalm, 2007). Challenging behaviours can be particularly difficult because their root causes can be widely varied. The behaviours can be a way of dealing with sensory disturbances or can be caused from internal frustration at not being able to communicate. Challenging behaviours can also be intrinsically rewarding. So removing an external reward may have no effect.

ABA has had good results when dealing with problematic behaviours. However, ABA employs careful analysis and responds accordingly: if a cause is found, strategies would be developed to address it specifically. Auti does not do this: if a behaviour has a cause, Auti will have no effect as it only addresses the behaviours itself. Also ABA goes much further than the discrete trial training described in the introduction, and challenging behaviours are often addressed with different strategies (Matson et al., 2012; Matson, Sipes, Fodstad, & Fitzgerald, 2011). For the removal of a reward to be effective in changing behaviour, it must be of greater value to the child than the relief or pleasure they are getting from their challenging behaviours. It may be that the freezing response used in Auti could be effective if it was integrated into a toy or interaction that was extremely valuable to the child. Though this was not seen in the current experiments.

**Classification.** Like Kahn et al.’s (2004) study, 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. Firstly, it helps us understand how the children viewed the toy; and, secondly, it raises the possibility of using Auti, or other robotic toys, in similar ways to how animals are used in Animal Assisted Therapy (AAT). However, although the results show that the children are distinguishing between the Interactive and Active Auti, the results do not explicitly compare the children’s interactions with the toy to those with an actual animal. Some of our anecdotal observations make it clear that at least some of the children were not
classifying Auti as an animal. Ten of 18 children behaved differently toward the sleeping dog than they did toward the Interactive Auti – asking if it was alive or a real puppy and being more cautious in their approach. With Auti, those children asked what it was, rather than if it were real, and were less cautious in their approach. According to the WCC theory of ASD, individuals with ASD have strong domain-specific processing and struggle with generalization. Therefore, in spite of children interacting with the Interactive Auti differently from the Active Auti, 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 that Interactive Auti is closer to animals than Active Auti is. Further research around classification is necessary to understand how ASD children classify the toy. It may be that research on Auti in an AAT protocol would be more informative, but the factors of AAT which are important are not yet clear. It may be that to get the benefits of an AAT protocol. It may not be necessary for the toy to be classified as an animal or animal-like, but that it just requires certain aspects of animal interactions.

The children who played with both the Active and Interactive Auti did not display significant differences between the numbers of classifications in each condition. This could have been for several reasons. It could be that the children categorised Auti when in the Active condition, where it had less animal-like features and then kept the same classification when the Interactive Auti was introduced. Alternatively, the within-subject comparisons only compared the first 10 minutes of play from each condition and there may not have been enough time for the different classification behaviours to become apparent. The children also played with the Interactive toy at the end of the session; so it is possible that, due to fatigue, they did not engage as deeply with the toy and thus did not display as many categorizing behaviours.

Extended Play. The hope with Auti was that its movements and appearance would, for children who were able, help bridge the gap to imaginative play. This appeared to happen for some children. The results showed the children displayed more extended play with Interactive Auti than Active Auti. Extended play was added as a category because there were differences in how children played with the Interactive and Active Auti’s that were not being captured by the initial classification category. This category encompassed the times when children went beyond the expected interactions with the toy.

One theory of ToM considers the cognitive function to be controlled by a discrete theory of mind mechanism (Baron-Cohen et al., 1985; Leslie, 1987). This mechanism is thought not only to deal with the attribution of mental states, but also the ability to attribute multiple representations to one object. This theory would suggest that the deficits in pretend play are due to dysfunctions of the ToM mechanism which make it difficult for children to decouple ‘real’ representations of an object (a plate) and couple it with ‘pretend’ representations (a steering...
A Study of Auti

play, pretending to feed the toy or build a house 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 and pretend play.

Generalization. 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 are 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, it may be that the children were only generalising to other toys the particular behaviours that the instructor had demonstrated with Auti. This would indicate that they were generalising behaviours learned from the instructor rather than from Auti, which is an important distinction to note. It is also worth noting that the generalized behaviour only occurred after the child had established that it wasn’t a real dog. This adds to the evidence that they were grouping Auti and the behaviours they associated with Auti in a ‘non alive’ category.

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 commented that no face meant that the toy didn’t ‘invade’ her child’s space. Six parents felt that because there was no face their children didn’t know what to do with it or lack of a face made the toy intimidating. The rest of the parents thought it was fine.

Another view of ASD deficits in pretend play comes from the EF perspective: if there are difficulties in the executive functions, then many aspects of play could become difficult. Children may struggle with inhibiting the ‘real’ aspects of a toy to allow for pretend representation, generating new play ideas, or shifting attention from one interpretation of the toy to the other. Rutherford and Rogers (2003) found that ‘generativity’ was the most important EF factor in pretend play. It may have been easier for the children to engage in pretend play with Interactive Auti because Interactive Auti reacted to their interactions and children only had to think what they would do next rather than having to generate their own ideas for what the toy would do as well.

It was noticed, anecdotally, 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.
either way. Though all parents liked the possibility of the face being an optional attachment like Mr. Potato Head. The thinking in the original design was 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.

In conclusion, we found that ABA principles of reinforcement delivered through a robotic toy can be effective in eliciting positive behaviours in children with ASD. This result showed that responsive motions are seen as a reward by some children with ASD. Interactive Auti was also effective in encouraging extended play and children classified it differently to how they classified the Active-only Auti. This means with further development, robotic toys may be helpful additions to ABA programs and other autism therapies, or they may be useful as tools on their own.

The study identified key areas for future development. The robotic toy was not found to be able to reduce challenging behaviours. Two ways which may be better at targeting the challenging behaviours could be explored: first, incorporating other ABA techniques for addressing challenging behaviours into Auti; and second, putting Auti’s responses into a toy to which the child already has an attachment. The behaviours elicited were also noted to become repetitive. Since repetitive behaviours in ASD do not need reinforcing, it would be useful to find ways to increase the range of behaviours the children use to activate the toy. One approach would be to explore robots that respond to more nuanced behaviours and incorporate technologies such as speech recognition. Investigating ways to support the generation of extended play ideas would be beneficial.

The study also highlighted areas where we need to know more about how children with ASD interact. In particular, looking at how their play varies with different levels of functioning and how they generalise play behaviours. Such studies would be helpful in addressing ASD through play.
References


Appendix 1 – Questionnaire

Interviews will be administered verbally and the answers audio-recorded.

Questions regarding the child’s play (Preliminary session)

What they have contact with

- Has your child played with robotic toys before?
- Does your child play with animals?
- What is your child’s behaviour like when interacting with animals?
- Has your child ever seen or interacted with a flip dog toy before?
- Has your child ever seen or interacted with the sleeping cat toy before?

Imaginative

- Do they interact with toys as if they are alive with thoughts and feelings rather than as an object?
- Does your child re-enact things they have seen with their toys?
- Does your child make up new stories when they play?
- Does your child see toys as representations of other things?
- Does your child make a toy represent new or other things? Eg a hat representing a steering wheel?
- Does your child play pretend games?
• Does your child ever make up a sort of story or sequence in play?
• Does your child engage in doll/action figure/stuffed animal play?
• Does your child ever use the doll/action figure as an indicator of action?
• Does your child ever make the doll/action figure talk or make noises?
• Does your child ever play imaginative games with someone else?
• Do they seem to understand that the other person is pretending? How can you tell?

Play behaviours
• How does your child generally play with toys?
• Does your child scream when interacting with objects/toys?
• Does your child scream when interacting with people?
• Does your child hit when interacting with objects/toys?
• Does your child hit when interacting with people?
• Does your child throw objects/toys?
• Are there common things that lead to problematic behaviours?
• Are there common things that lead to positive behaviours?
• Does your child take the lead in play or follow others’ ideas?
• What do you do to encourage play?

Questions regarding the child’s interactions at home and the nature of the home environment (Preliminary session)
• Does your home have pets?
• Does your child interact with your pets?
• Do they do this frequently? Rate on a scale of 1-5: 1-seldom, 5-often?
• Does your child have brothers and sisters at home?
• Do they interact easily with their siblings?
• How does your child interact with new things?
• How does your child interact with new people?

Questions regarding empathy (Preliminary session)
• Can your child recognise differ emotions in other people?
• Is your child able to understand other people’s feelings? (e.g. understand why others feel the way they do.)
• Does your child respond to other people’s emotions?
• How do they show different emotions themselves? Which ones do they show?

Questions regarding cognitive function (Preliminary session)
• Does your child have any additional learning difficulties?

Questions regarding treatments (Preliminary session)
• What therapies/ techniques do you use at the moment?
• What therapies/ techniques have you tried in the past?

Parents’ point of view (End of testing)
• Do you see Auti as a positive thing?
• Would you use an Auti?
• Did you like how Auti looked?
• Would you want an Auti in your home?

• Would you prefer Auti in different colours?

• Do you feel Auti could help your child’s play? On a scale of 1 to 5 (1 being very little, 5 being a lot), how helpful do you think Auti would be?

Questions if there is a follow-up trial

• Did your child talk about Auti after the trial?

• Did your child mention Auti in the times between the trials? How often? Is this typical behaviour?

• Did your child look forward to having Auti come again?

• Did your child require an incentive to play with him again?
Appendix 2 – Information Sheet and Consent Form

What is the purpose of this research?

Recent studies have shown children with autism have a partiality for robots. Studies are now looking at how children can be taught through this medium. This research looks at discovering how children learn from a particular robotic toy – Auti. Auti is a new toy specifically designed for children with autism, which aims to help develop positive play behaviors. Auti is the only toy developed which specifically distinguishes between positive and problematic behaviors. The hope is that this research will guide the development of the toy, keeping the needs of the children central in the process. The research will be beneficial to our understanding of how children interact with the different aspects of this robotic toy, and we hope it will result in the development of a promising teaching tool.
Who are we?

I, Helen Andreae, am a masters student in psychology and I am the creator of the toy. Dr. Jason Low is a developmental scientist with research experience with children with autism. Dr. Deirdre Brown is a clinical psychologist and developmental scientist with research experience with children with developmental delay. This research has been approved by the School of Psychology Human Ethics Committee under delegated authority of Victoria University of Wellington’s Human Ethics Committee.

What happens if you agree to take part?

Taking part will involve your child interacting with three toys, a walking dog toy, Auti, and a fake sleeping dog. The study will take place over two or three sessions; a preliminary visit, the main study, and if you are willing, a short follow-up study. (You can see the flow chart of the main trial on the next page.)

We will bring the toys to you; you are not required to travel. We will also video record the sessions; this is to help us go back and see ‘in detail’ how your child interacted with the toy. In this study there are two groups, one group will interact with an interactive version of Auti, the others will interact with an active version, which moves but does not respond to the child’s behavior.

In the first visit, I will help your child start to become familiar with me. I will discuss with you the best way to do this. I am happy to send you photographs of myself and detailed schedules of what we will be doing together, if this makes it easier.

I will do some tasks that assess your child’s verbal and nonverbal skills. This is to make sure that each group of children we work with has children of similar abilities in it. We will also ask you to answer a questionnaire about your child’s abilities and behaviors and ask you some questions about their development. We will audio-record these sessions so we can remember your responses. Once we have processed the responses, the recordings will be wiped. We expect the first visit to take about an hour.

The main study will take between 2 ½ to 3 hours, during this session your child will alternate between playing with the toy and engaging in a self-directed play activity of their own that they prefer or having a snack.

Your child will be first given the walking dog toy for 8 minutes; they will then be given Auti for 15 minutes. This will complete the first session and they will have a break. In the second and third session they will only interact with Auti. Each of these sessions will last for 15 minutes followed by a 20-minute break. In the last session after 15 minutes with Auti, we will put the sleeping cat in the room and take Auti away, this segment will last 5 minutes.
During the sessions, it would be best if other siblings were kept out of the room, as they could be a distraction. We can talk to you about how to best manage this. If possible, we would also like you to be present for some of the time your child is playing with the toy. In this time we wouldn’t be asking you to play with your child but if they engage with you, we want you to respond as you would normally. We can talk about this in more detail during the initial visit.

We will also have some short questionnaires for you to fill out. They look at:

- Your child’s history, for example, “Do you have pets which your child interacts with?”

- What you thought of the toy, for example, “Do you see Auti as a positive thing?”

If you are willing, we would also like to do a short follow-up study, this would consist of another 15 minute play time with Auti and a very short questionnaire. You are welcome to decide about the follow-up session at any time, and you may still take part in the main study, even if you choose not to take part in a follow-up session.

**What happens to the information you provide?**

You and your child’s names will be kept confidential. We will do several things to make sure this is the case:
• You and your child’s name will be coded, and be kept separately from the data collected, this means the data will only refer to you as participant 1, 2, 3...

• Your coded name will be kept in a locked file in Dr. Jason Low’s office.

• After the video and audio recordings have been coded they will be wiped.

• The electronic data, which will includes things like the number of times participant 7 patted Auti in session 3, will be kept electronically. Helen Andreea, Dr. Jason Low and Dr. Deirdre Brown will have copies of this data. This data may be shared with other competent professionals. This is in case another researcher wants to check that we did the research correctly. No names or identifying features are shared.

• All the data will be wiped after 5 years.

Thank you for your participation

As a token of our appreciation, at the end of the study, you will receive a miniature stuffed Auti toy, or an Auti bookmark for your time and effort.

Some of the information you provide may be present in a student thesis. We may publish the overall findings from our research in a scientific journal or present them at scientific conferences. The results may also be used to inform the commercial development of the toy. This would mean that the results might be used when pitching the toy to potential investors, or in promotion of the toy. The results would contain no identifying information.
Consent to Participate in The AutiToy Study

If you wish to take part in the proposed study, please read the following carefully and sign in the space provided.

I have read the information concerning the proposed study and I am aware of the type of information that is required from my child and me as participants. I understand that the above study is voluntary and that we don’t have to take part in it. If my child or I want to stop at any time, we can, and all data and recordings will be destroyed and not included in the study.

I understand that the information I give is confidential and will be used only for the purposes of the proposed study, and that I will not be identified. I also understand that the study is confidential.

I understand that my child will be video recorded during the sessions.

I understand that my interviews will be audio recorded.

I have had the chance to ask questions about the research and have those questions answered to my satisfaction.

I agree to take part in this study and that my child can participate in the Study.

Name: ......................................................................................................................

Signature: .............................................................................................................

Name of participating child: ..............................................................................

I would like a copy of the summary of the results of this study:

NO ☐ YES ☐

Please send the summary to the following email/ postal address (please write address below)