SOCIALLY ASSISTIVE ROBOT ENABLED HOME-BASED CARE FOR SUPPORTING PEOPLE WITH AUTISM

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Abstract

The growing number of people diagnosed with Autism Spectrum Disorder (ASD) is an issue of concern in Australia and many countries. In order to improve the engagement, reciprocity, productivity and usefulness of people with ASD in a home-based environment, in this paper the authors report on a 9 month Australian home-based care trial of socially assistive robot (Lucy) to support two young adults with autism. This work demonstrates that by marrying personhood (of people with ASD) with human-like communication modalities of Lucy potentially positive outcomes can be achieved in terms of engagement, productivity and usefulness as well as reciprocity of the people with ASD. Lucy also provide respite to their carers (e.g., parents) in their day to day living.

Keywords: socially assistive robot, autism home-based care, person-centred and lifestyle centred service, positive engagement.

1 INTRODUCTION

The growing number of children diagnosed with Autism Spectrum Disorder (ASD) is an issue of concern both in Australia and the world. This concern is reflected in the 2008 resolution of the United Nations General Assembly for a World Autism Awareness Day (United-Nations-General-Assembly 2008). A 2006 report was the first study to estimate prevalence rates of children with ASD across Australia. The study made different estimates based on different data sources. Based on Centrelink data, the 2006 report estimated a prevalence rate of ASD of 62.5 per 10,000 (or one in 160) for 6-12 year old children. A report based on data from the 2009 Survey of Ageing, Disability and Carers estimated that 64,600 people in Australia had ASD but noted that this might be an underestimate (Australian-Bureau-of-Statistics 2009).

Autism is a developmental disorder that encompasses a wide spectrum of impairments in social skills, communication and imagination. Most of current research focuses on the use of robots in the early diagnosis of autism (Campolo et al. 2008; Scassellati 2007), promoting self-initiated interaction (Feil-Seifer et al. 2008a; Robins et al. 2005), helping children with autism in turn-taking activities (Dautenhahn et al. 2004), join attention activities (Duquette et al. 2008; Ravindra et al. 2009) and imitation therapy (Bird et al. 2007; Duquette et al. 2008). However, research on using socially assistive robots to improve the emotional wellbeing of the people with ASD, entertain and assist them in their daily basis has not been explored in the literature much. Emotional wellbeing is one of two aspects of personal well-being that can be measured in quantitative quality of life assessments (Kahneman & Deaton 2010) and is a critical part of an person to help them live gracefully and remain independent as well as integrated with society. The existing research on socially assistive robots and companion robots with limited human attributes constrains the range and level of emotional engagement with their human partners and their ability to influence emotional wellbeing in terms of developing reciprocal relationship and making them more productive and useful..

In order to enhance the emotional wellbeing of the young people with ASD, the authors in this paper report on research conducted in families with people who have autism using a socially assistive robot called Lucy. The research makes the following contributions: a) designing lifestyle centred Lucy enabled services underpinned in the concept of personhood in people with autism (two young adults in the case study) ; b) integrating the delivery of lifestyle centred services with Lucy's human-like communication attributes of voice, emotive expressions, head and body motion in dancing style to generate positive emotional engagement in person with autism and breaking technology barriers; c) providing flexible interaction modes with Lucy using voice, touch panel and/or face involving cloud computing and computer vision techniques to meet disability needs and comfort requirements of person with autism, and d) developing reciprocal relationship through 'a', 'b' and 'c' to make persons with autism more productive and useful (thus impacting on their overall emotional wellbeing) in a home-based care environment as well as provide respite to their carers (e.g., parents) .

The paper is organized as follows. The next section outlines the existing work in ASD. This is followed by specifications of Lucy, theoretical foundations of robot service design, constructs used for trial, data collection instruments, trial design and trial results or findings based on case study of the two young adults with autism. The trial results are then discussed in a separate discussion section which includes practical implications of the research as well as its limitations. Theoretical implications of research are also outlined followed by conclusion of the paper.

2 EXISTING WORK

Technologies such as computer technology (Bernard-Opitz et al. 2001; Liu et al. 2008; Moore et al. 2000), virtual reality (Conn et al. 2008; Lahiri et al. 2011; Welch et al. 2009) have been utilized for the purpose of creating a beneficial learning environment for children with ASD. Although robots have been

suggested as tools to aid in the early diagnosis of autism (Campolo et al. 2008; Scassellati 2007), the majority of research focuses on developing robots and novel therapies that help alleviate symptoms in children that have been previously diagnosed (Bird et al. 2007; Duquette et al. 2008). The main intended role of a robot in autism therapy is to allow or encourage children to develop and employ social skills. Robots were designed to take part in numerous different interaction goals, such as improving self-initiated interactions, mediating turn-taking, assisting in emotion recognition, maintaining attention, evoking joint attention and eliciting imitation (Ricks et al. 2010) as the deficits in the social and communicative skills of children with ASD.

In order to assist children with ASD in the use of facial expressions, and other social behaviours that regulate engagement, many studies adopted assistive robots with designed goals to elicit and maintain active engagement and attract attention of children with ADS through timed movement, social requests, and the display of desirable behaviours (Emi Miyamoto et al. 2005; Feil-Seifer et al. 2008b; Ferrari et al. 2009; Kim et al. 2012; Kozima et al. 2007; Michaud et al. 2002; Pioggia et al. 2007; Robins et al. 2004a; Stanton et al. 2008). These behaviours have been encouraged by having the robot react to the child's actions. Playing chase games with the child (Dautenhahn et al. 2004) or blowing bubbles when the child presses a button on the robot (Feil-Seifer et al. 2008a) are examples of such activities. Other activities involve asking the child to identify the emotion a robot's face is displaying (Duquette et al. 2008; Pioggia et al. 2005), or to look in the direction the robot points (Ravindra et al. 2009). In some activities the children directly interacts with the robot by themselves with a parent or clinician on hand to help encourage this interaction (Pioggia et al. 2005; Ravindra et al. 2009) while in other scenarios a therapist is involved and plays a more active part in the therapy (Kozima et al. 2005; Robins et al. 2006).

Joint attention, the ability of demonstrating shared interest toward objects by pointing or using eye contact is another difficulty of children with autism. In many studies, children with ASD interacting with robots show spontaneous joint attention behaviours such as looking at an adult and back to the robot or pointing to the robot and looking at an adult with the intention of sharing some feature with that person (Feil-Seifer et al. 2009; Ferrari et al. 2009; Kerstin Dautenhahn et al. 2009; Kozima et al. 2005; Kozima et al. 2007; ROBINS et al. 2004a; Robins et al. 2009; Robins et al. 2005; Werry et al. 2001). In some studies, assistive robots are pre-programmed with behaviours that simulate attention from the robot's perspective. For instance, Keepon (Kozima et al. 2007) can orient itself toward a user's eyes and then toward an object in an apparent display of joint attention.

Other research focused on assisting children in imitation. Sometimes the imitation is structured, in that children are encouraged by adults or by the robot itself to imitate the robot's actions (Bird et al. 2007; Duquette et al. 2008; Ferrari et al. 2009; Pioggia et al. 2008; Robins et al. 2004b; Robins et al. 2005). Other imitation occurs spontaneously and develops into a game, with the child imitating the robot's behaviours and vice versa (Kozima et al. 2005; Kozima et al. 2007; Robins et al. 2009). These behaviours have been encouraged by having the robot react to the child's actions. Playing chase games with the child (Dautenhahn et al. 2004) or blowing bubbles when the child presses a button on the robot (Feil-Seifer et al. 2008a) are examples of such activities.

Other studies focused on improving sharing and turn-taking ability of children with ASD. In these studies, children learn important life skills through social games involving turn-taking, so the ability to engage in these behaviours is important for development. Through their status as an explicit social presence, robots can elicit turn-taking with children who tend not to engage in such behaviour (Ferrari et al. 2009; Kerstin Dautenhahn et al. 2009; Kozima et al. 2007; Robins et al. 2005)

To the best of our knowledge, limited existing work has systematically studied the impact of socially assistive robot on elements of emotional wellbeing of the children with ASD, especially in the context of Australian home-based care. Our research is different from existing work in the following aspects: First, most of existing work focused using robots as therapeutic or treatment tools to improve impaired skills of the children with autism. Differently, we focused on using social robots to enhance sensory enrichment

(i.e., entertain them with singing and dancing), assist them in their daily basis (tell them weather today to assist choosing suitable clothes or remind them daily tasks). Second, the researches on therapeutic-assisted robots were conducted in short therapy sections or classroom environments. We conducted a longitudinal trial with young people with ASD in home-based environment and this is the first ever Australian home-based trial. In addition, Lucy used in the research trial is with rich human-like functionality involving voice, gestures, emotion and combination of human attributes and can be personalized to preferences and lifestyles of people with ASD.

3 SPECIFICATIONS OF LUCY

Lucy as shown in Figure 1 is ~39 cm tall and weighs 6.5 kg. Lucy's human attributes include baby face like appearance, voice vocalization, face recognition, face registration and face tracking, facial expressions, gestures, body motion sensors, dance movements, touch sensors, emotion recognition and speech acoustics recognition.

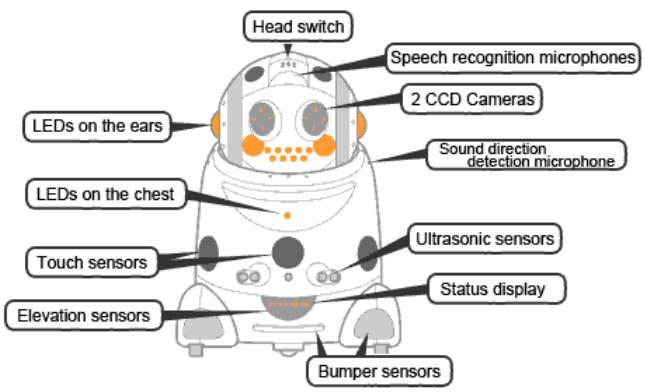

Figure 1. Lucy's specifications (left) and Emotive Expressions (right – orange color) with sibling Charlie

The field trials have been designed with the aim of evaluating the impacts of Lucy in the context of Australian home-based autism care. In this context the robot service design methodology is outlined next.

4 THEORETICAL FOUNDATIONS OF ROBOT SERVICE DESIGN

Person-centred approaches have come to dominate the rhetoric associated with the design and delivery of residential, vocational, educational and recreational supports for adults with intellectual disabilities. Recently, health care researchers have shown the need for promoting person-centred care, self-identity and personhood for people with mental disabilities (Beadie-Brown et al. 2009, ABS 2010; Cohen-Mansfield et al. 2006; O'Connor et al. 2007). Given the importance of pursuing this path, this research involves marrying personhood with Lucy's human-like communication modalities (e.g., voice, gestures, expressions, head and body movement), computer vision techniques (e.g., face recognition) and cloud computing based communication techniques (e.g., using tablet and touch pads to give instructions to Lucy) to realize a symbiotic robotic system.

Research in this area has indicated that negative consequences of autism can be mitigated by designing an approach towards care that respects and supports each individual's personhood (Beadie-Brown et al. 2009). Personhood has been defined as 'the standing or status that is bestowed upon one human being, by others, in the context of relationship and social being (Kitwood, 1997). It includes three fundamental components, namely, interactional environment, subjective experience and social context. Figure 2 shows mapping of concepts related to these three components in Lucy.

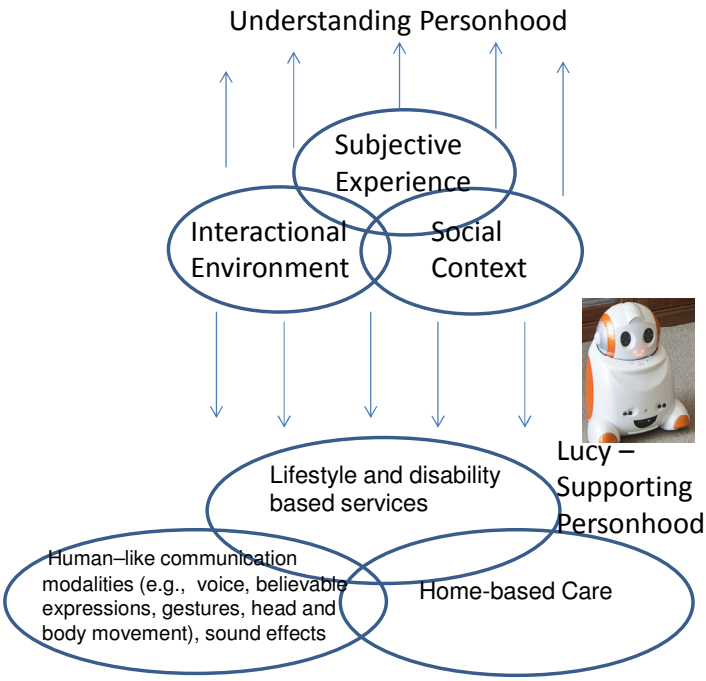

Figure 2. Lucy's service design methodology based on personhood

4.1 Modeling Subjective Experience in Lucy

The subjective experience in an autism care context involves design of services personalized around the lifestyle of the person with autism. These lifestyle based services which reflect their personhood are designed to engage and help them become more productive and useful. The need for engagement and usefulness is relevant in a home-based care environment where assistive technologies need to support the parents (carers) through partially or wholly independent interaction of Lucy with person with autism for limited periods. Based on our successful deployments of robots like Lucy in other domains (e.g., dementia) to support people with disability and mental health issues (Khosla and Chu, 2013) we have modelled the subjective experience in the context of emotional well being of persons with autism (Health 2010). The five constructs related to emotional well being are sensory enrichment, social connectivity, productivity and usefulness, needs and comfort and resilience.

4.2 Modelling Interactional Environment in Lucy

The embodiment of interactional environment in Lucy involves modelling of human characteristics like gesture, emotion and expressions, voice, motion and dancing and dialog adaptation. It involves marrying various services provided by Lucy with its communication modalities like voice, emotive expressions (e.g., blushing – Figure 3), head and body movements with different range, intensity and combination depending on service context so as to facilitate positive emotional engagement (e.g., responding with positive expressions and actions (e.g., kissing the robot) and reciprocity (e.g., calling robot by its name, responding to its recommendations, etc. from its human partner.

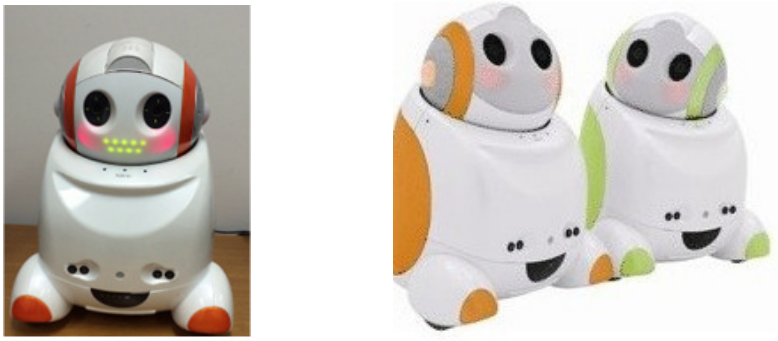

Figure 3. Lucy blushing expressions

4.3 Modelling Home-based Care Context

Unlike in a supervised environment (e.g. in a school or community setting) in a home-based care context Lucy's services have to delivered in a partially or wholly independent manner. Thus different users may prefer different interaction modes. In Figure 4 four interaction modes with Lucy are shown, namely, using voice, touch panel, smart phone or face i.e., face recognition)

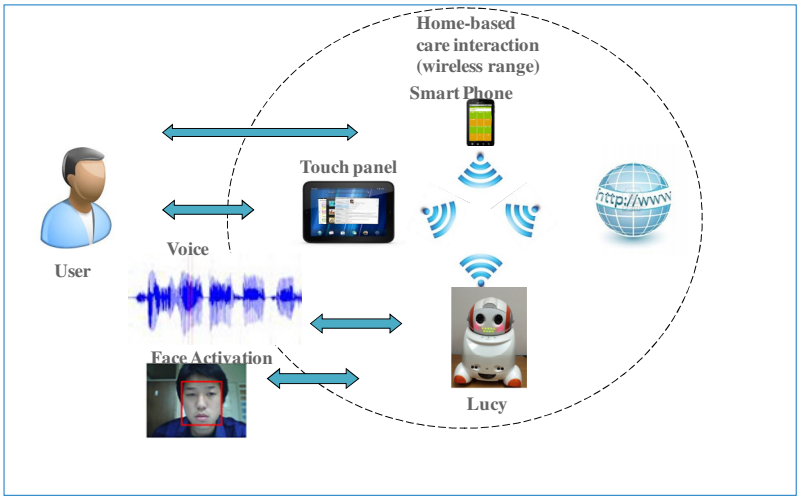

Figure 4. Lucy enabled home-based care trial environment

5 TRIAL DESIGN AND RESULTS

Trial design is underpinned in a case study of two adults with autism in a Melbourne household in Australia. Figure 4 also shows the trial environment in the Melbourne household

Table 1 shows the mapping between subjective experience and emotional wellbeing constructs (Health, 2010) and corresponding lifestyle based services designed to be delivered by Lucy to two persons with autism in a Melbourne household in the state of Victoria in Australia. The parents have an adult Daughter (D) aged 3 and Son (S) aged 25 who have autism. The parents expect that Lucy (social robot) would help to make their daughter more productive by supporting them with household chores and enable their son to improve his hygiene habits. In the process it will also help to provide them some respite.

The lifestyle based services for D and S include Lucy singing and dancing to their favourite songs, Lucy reading books selected by them, playing hygiene habit based quiz as well as providing reminders to them. The next section will elaborate on how these services have been designed.

Subjective Experience and Emotional Wellbeing construct	Lucy's services
Positive Emotional Engagement through Sensory Enrichment	Sing and dance Interactive storytelling Reading news
Social Connectivity	Playing game (e.g., Bingo) Phone calls Lucy enabled social connectivity using smart phone
Needs and Comfort	Flexible communication modes (e.g., voice commands, touch panel based commands to robot)
Resilient, Productive and Usefulness	Quiz , playing game, reminder, telling weather, interactive storytelling

Table 1. Mapping between Lucy's five constructs and services

5.1 Positive Emotional engagement, sensory enrichment

The functional model parameters for modelling positive engagement and reciprocal relationship are based on design and delivery of personalised services underpinned in the lifestyle choices of the person involved. These include music and songs, news and stories personalised to their taste and positive episodic experiences, social needs, and family history, As shown in Table 1 services shortlisted for trial are singing and dancing, interactive storytelling, and reading news, playing bingo, making phone call and Skype.

5.2 Productivity and Usefulness

The ability to play a meaningful and productive role in their daily life can be important to the emotional wellbeing (Health, 2010). Being able to engage and contribute to themselves and family makes them feel useful. In this context quiz and reminder based services have been designed for persons with autism. The quiz includes questions to improve their basic knowledge and toilet hygiene, make them productive in their daily living. The reminder is used to help them participate in family chores productively.

5.3 Interaction modes with Lucy

Flexible communication modes are considered as an important component for enabling Lucy to personalize care for people with autism (given their physical abilities and mental faculties). At home, mother, daughter and son can communicate with Lucy using voice and smart phone (mother) and touch panel (daughter and son) respectively. The touch panel is provided with graphical buttons for various services. The design of the touch panel facilitates perceptual processing (rather than cognitive processing) for ease of use. The various communication modes are enabled through cloud based computing, computer vision and speech recognition techniques.

5.4 Data Collection

The data collected from trial involves: Lucy's video recording of interaction of users participating in activities and validation of video data with feedback with activity pattern log files in Lucy and interview with parents. The various sources of data collection facilitate content validity of measurement of emotional engagement, reciprocity and productivity (Lynn 1986).

A Case Study - Daughter (D)

D is a 23 ears old young lady with autism who lives in Australia. She lacks self confidence, has limited social skills and has difficulty holding short conversations. As her mother has put it "Melissa is a young

lady who needs a structured environment to engage her in activities that stimulate and motivate her. Without activities that engage her she will engage in obsessive compulsive behaviours." Her parents want her to be more productive at home rather than simply watching TV programs for most of the day. She has a very short attention span and lacks motivation to learn. She would like her to be more productive and help out in household chores and also improve her hygiene habits so that her mother can get proper sleep at night. Existing technological devices like iPad cannot engage her for long.

Lucy (social robot) has been deployed in D's home for a period of 9 months. During this time, D has taken initiative and engaged with Lucy independently. She maintains eye contact with Lucy without hesitation.

She has developed a reciprocal relationship with Lucy in this period. Lucy reminds D to take clothes off the line and rewards her by singing and dancing to her favorite songs. D has played Bingo (number game) with to improve eye and had coordination skills. Lucy has done several quizzes with D related to her toilet hygiene.

Figure 5 (a and b). D is enjoying the music played by Lucy. (b) S (her bother) is excitedly looking at photo (sent remotely by their sister) projected on a screen by robot Lucie © SBS Insight

Her mother reported that now her concentration span because of multi-modal sensory enrichment provided by Lucy. Once Lucy was brought back to research centre for upgrade, on its return to D's home her mother reported "Melissa was delighted to see Lucy on the table. To my surprise she gave her a kiss. I wish I had got a photo of this it was very cute." D particularly enjoyed emotive expressions and gestures synchronized with various dancing themes.

In order to leverage the reciprocal relationship between Lucy and D, her parents can also send messages from their smart phones to Lucy for broadcasting to D. D's mother had this to say "I sent D a message could she please come and turn the light on. D was in the lounge room watching TV. And she did. Next time I will do the same but will get her to put the kettle on as well. I think we can build up to her making me a cup of coffee then turning the light on. All a bit of fun but we can build on this." Her mother had this to say after nine months of deployment of Lucy in their home Melissa's concentration span has improved over this period. I guess it is difficult to know what has contributed to this but no doubt the engagement with Lucy has certainly helped. The music and in more recent time the talking stories have improved Melissa's ability to sit and listen (figure 6).

Figure 6. D and S are jointly listening to a story narrated by Lucie

Melissa has increased her verbal vocabulary. Some of these can be directly contributed to Lucy as the words are constantly repeated.

The Bingo game is a wonderful addition (Figure 7). The modified bingo game has provided an activity we can play as a family. There are not too many games we can sit around the table and play. D has really surprised me with her ability to play this game with actually less assistance than S (D's older brother who also has autism). S does not seem to have the same enthusiasm for it. We started with numbers 1 to 20 which Melissa and S have mastered reasonably quickly. We have now increased the numbers to 1 to 30. It's important to constantly provide new challenges for both Melissa and Christopher but not make the challenges to great that the skill is to difficult or they will loose enthusiasm.

Figure 7. D and S playing Bingo with their mother ©SBS Insight

Since introducing a chocolate frog for the Bingo winner D's concentration has improved greatly while playing the game. Especially when she won a couple. D even came out with a new word or should I say greeting. "Ge-day". It will be interesting to see if she plans to use this greeting away from Lucy.

The calendar reminders are great especially in the afternoon to remind D and S to assist with a few house hold chores. These include emptying the dishwasher and getting the washing of the line. On Wednesday we have a carer from 3pm to 6pm. Lucy reminds our carer, D and S of the chores that need to be completed. As neither their father or I are home till six pm. We have really had Lucy working without issues well over the last 3 months or so. Until then it was at times a little frustrating with Internet drop out. This has prevented greater involvement from our carer. But these things take time and patience. Our carer Catherine is now using Lucy for the talking stories and to play Bingo and has even been confident enough to teach a fill in carer how to use Lucy."

Analysis:

The ability of Lucy to improve the subjective experience of D in her daily life through singing and dancing to her favorite songs, playing games like bingo and interactive storytelling have not only provided her sensory enrichment but also made her more productive and cooperative at home. The rich human-like interactional abilities of Lucy delivered in embodied form differentiate it from other screen based technological devices by positively engaging D for longer periods of time and developing reciprocal relationship with D in terms of rewarding her for household chores. The rich sensory enrichment provided to D through singing and dancing motivates her to interact with Lucy in learning activities like interactive storytelling and playing Bingo. Playing Bingo with Lucy is also a family-oriented activity which brings family together.

In a home-based care context, the above interactional activities with Lucy provide diversion therapy to D and can also help to mitigate stress situations. The engagement with Lucy which lasts anywhere between 20 minutes to 1 hour on a typical day help to provide respite to her parents. The encouraging results of the ongoing trial with D also point in the right direction of using the personhood model to design services in Lucy.

Case Study - Son (S)

S is a 25 year old young adult who has different autistic traits compared to D. S likes to interact with technological devices. The main concern about S is about his toileting and personal hygiene. Also, his parents would like him to be motivated to learn.

Figure 8. (a) S positively engaged with Lucy in interactive storytelling and (b) S pointing to the horse in the book based on Lucy's creation of sound effects of a horse © SBS Insight

Figure 8a shows coordination between Lucy telling the story and S reading the book. Figure 8b, on the other hand depicts comprehension by S that the sound effect being made by Lucy is that of a horse as pointed out by S in the book. S's mother had this to say "While I am writing this. S's father took him outside for a bit of fresh air but S has come back inside and grabbed the books and put Lucy back into the reading program. Way to go team."

Playing quiz with Lucy has positive impact on mental activity and sense of usefulness to the persons with autism. As shown in Table 2, the quiz consists of 10 questions has been written by the D and S' parents which aims at helping them to learn or memorize some basic knowledge or daily routines. The number of correct answers in each try is recorded as shown in figure 10. All the participants used touch panel to provide the answers to Lucy. Lucy provided the correct answers and the feedback to the users on number of questions they got right with a consistent encouragement (i.e., "Very well done", "Well done, you absolutely can do better next time", etc) regardless how good the results are. As evidenced by the feedback from the parents and health care workers, the quiz activity provided a sense of usefulness to the participants.

Question	Choices
What kind of animal is Tilly?	1. Cat; 2. Elephant; 3. Dog
Mandy has a job as a?	1. Truck driver; 2. Gardner; 3. Teacher
What colour is dad's shirt?	1. Red; 2. Green; 3. Black
Before I go to bed at night I need to?	1. Say goodnight to mum and dad; 2. Remember to clean my teeth; 3. Both Clean my teeth and say good night
When I have been to the toilet the next thing I need to do is?	1. Push the toilet button; 2. Turn of the light; 3. Wash my hands
When I have been to the toilet and I have pushed the toilet button I then need to?	1. Turn off the light; 2. Wash my hands; 3. Dry my hands on the towel
What colour is the sky?	1. Yellow; 2. Green; 3. Blue
When I have been to the toilet and I have pushed the button and washed my hands Then I need to,	1. Leave the bathroom; 2. Dry my hands; 3 turn off the light
what time does Peter the taxi driver come during the week,	1. Eight O'clock; 2. Ten O'clock; 3. Six O'clock
When I have been to the toilet and I have pushed the button. Then I have washed and dried my hands. Then I need to	1. Turn off the light; 2. Leave

Table 2. A sample quiz written by the carers (parents) of the participants

The log data shows that through prompting and vocalizing the right answers to the D and S, they can learn basic knowledge which helps them in their daily life (Figure 9). One of the parents comments out that their son remembers to "turn of the lights" and "wash their hands" before leaving the toilet.

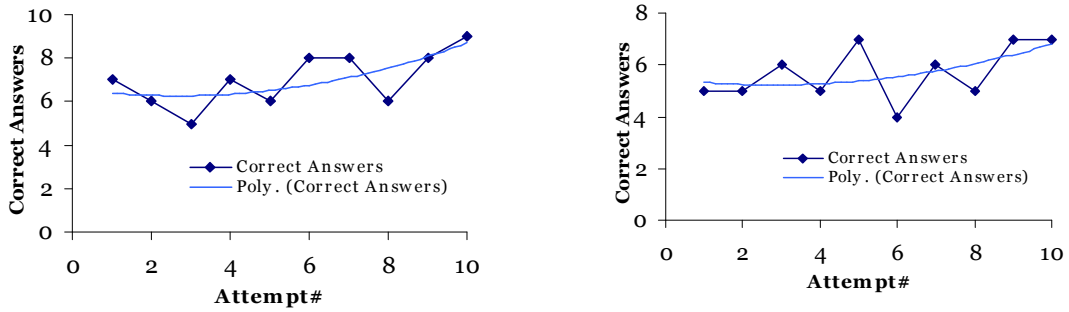

Figure 9. The number of correct answers of S (left) and D (right)

Figure 10. (a) S play quiz with Lucy and (b) washing hands based on quiz based hygiene learning activity with Lucy

D and S's mother had this to say "By creating a fun short quiz with a high success rate so as to engage either D or S in a learning activity we are hoping these skills are then transferred to actual activity. We have seen a degree of success with S who was transferring a toilet schedule to the actual activity (figure 10)."

5.5 Activity Patterns

In this section we corroborate the qualitative comments made by the parents with actual activity patterns of D and S as logged by Lucy in 9 months of deployment. By socially engaging the people with autism with Lucy through familiar activities which they are doing in their daily life, we are able to break technology barriers and encourage acceptance of Lucy. This has led to people to interact and reciprocate to Lucy on a one-to-one basis. The statistics of the log activity data (figure 11) recorded during the trials show that the participants maintain the frequency of interactions with Lucy, with an increasing interest in singing and dancing activity. The frequency variation in the 9 month period are indicative of need to update Lucy with new stories, new songs, quizzes, etc..

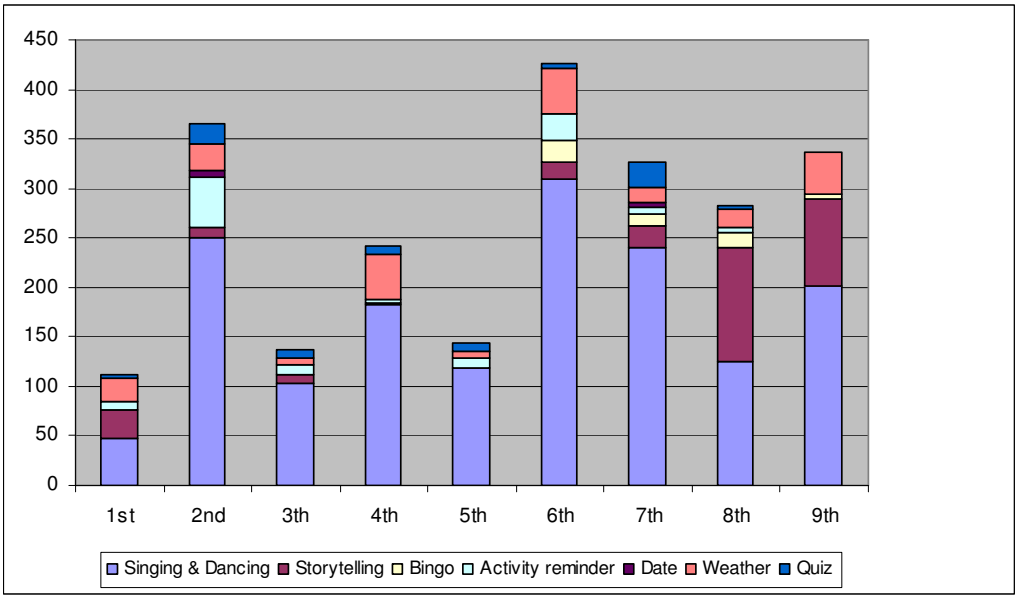

Figure 11. Frequency of interaction with Lucy

This activity was initially done the authors and the delays to an extent impacted upon the novelty of the services for D and Sin say 3, 4 and 5 respectively. At the time of writing this paper the updates can now be done by D and S's parents which is very liberating for them. Also, the variation can be due to family going on holidays. Additionally, one-to-one activities like Lucy reminding D and S about their calendar of activities for the day are other services that have been used by them to make them more resilient. The calendar services are delivered by Lucy automatically (i.e. not initiated by D or S) they are not recorded per say. Their frequency will depend upon the actual calendar for a day and will vary each day and month. Furthermore, by integrating the favourite songs and books of the trial participants into service design allows Lucy deliver personalized care to D and S.

6 DISCUSSION, PRACTICAL IMPLICATIONS AND LIMITATIONS

The experience of positive emotions is an important component of emotional wellbeing. However, autism may impede the ability of a person to pursue pleasurable moments and young people with autism may

have limited opportunity to engage in meaningful activities and, in particular, activities that are focused on a positive emotional response in a home-based environment. This research demonstrates that social robots like Lucy with human-like characteristics involving voice, gestures, emotion and combination of human attributes with personalized services (i.e., favorite songs, books) can be potentially used in home-based environments to generate positive emotion and provide sensory enrichments to young people with ASD. In addition, the results of this study indicate that the human-like characteristics in combination with personalized service design facilitate the acceptability of Lucy among young people with autism; D and S accepted the daily prompts of Lucy which allow them become more productive and useful. Lucy can also be used as a learning tool to help D and S with ASD learn basic skills which are then potentially transferred to actual activity.

In terms of practical implications, the work provides important support for the idea that beside the role of diagnosis and treatment for people with autism as studied in existing work, robots like Lucy may be used in home-based environments as a supplement to provide sensory enrichment to young people with ASD, assist them to be more productive and useful which finally provide some respite to the carers (i.e., parents). Lucy is non-judgemental and D and S did not complain of any problems in terms of interacting with Lucy. There has been continuous demand for more services. In future a network of Lucys will be trialed for supporting people with autism and increasing the range and variety of services.

This research was limited primarily by the sample size. The success of this field trial has encouraged us to involve more people with autism in the future in more home-based environments. This work has not considered aspects related to diagnosis of autistic behavior in people with autism which will be the focus of future work. We are also working on increasing the duration of interaction between the person with autism and the social robot in a 24 hour day.

7 THEORETICAL IMPLICATIONS OF WORK

There are two theoretical implications of this research. Firstly, socially assistive robots need to be designed in a social context. Within the social context the robot enabled services for the human partner need to be underpinned in concept of personhood to enable engagement and reciprocity. Secondly, the human-robot interface should be believable for breaking technology barrier and to facilitate a long term meaningful reciprocal relationship between assistive robot and young people with autism. This aspect has clear implications for design of interactional environment and communication modalities, and ornamental design of the robot to enable its productive use. Lucy, in this context provides a rich range of communication modalities to create believable expressions for services delivered by it. It also operatives as friendly interactive hub for integrating all pervasive devices in the home.

8 CONCLUSION

In this paper, we have presented the outcomes on the first ever longitudinal home-based field trial of social robot (Lucy) with young people with autism in Australia. By embodying the concept of personhood in Lucy and delivering personalised services with a rich variety of human-like communication modalities meaningful positive changes in daily lives of young adults with autism in a home-based care environment have been realised. Multiple sources of collection of data including interviews, and logging of actual activity or interaction patterns have been used to enhance the content validity of measurement of emotional engagement, reciprocity and productivity constructs related to emotional wellbeing and subjective experience of the person with autism. The trial in the 9 month period has provided hope and respite to the parents. In future, we are adding new services and enhancing existing ones. Lucy has successfully eliminated the barriers of use of technology by people with autism, and more importantly has had a positive impact on their productivity and usefulness, contributing to enhance their quality of life.

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