Service Personalisation of Humanoid Robot for Autism Care

***Abstract*—This paper demonstrates an innovative application in the context of autism using a Humanoid robot. A 9-month long home-based care trial with 191 hours of interaction is conducted to investigate the engagement with two young people with autism through adaptation on service design (e.g., change from narrative voice to more interactive story telling using emotion expressions, sounds effects and background music) and service personalization (service novelty). It involves big data collected to learn the participants' preferences and activity patterns. The experimental evidence on how to improve the long-term benefits of use of social robots is reported. The research establishes that in home-based care a Humanoid robot can maintain their engagement with young people with autism through service personalization over long periods of time.**

Keywords: Humanoid robot; autism; personalisation

I. INTRODUCTION

The issue of autism has been the rising concerns lately. A lack of effective support is greatly needed other than the medicine treatments. Especially emotional wellbeing is a critical part to person with autism who prefers to live independently at their own pace and remain connected with society. Existing research primarily focuses on the use of robots in early diagnosis of autism (Campolo et al. 2008; Scassellati 2007), promoting self-initiated interaction (Feil-Seifer et al. 2008a; Robins et al. 2005), helping in turn-taking activities (Dautenhahn et al. 2004), boosting attention activities (Duquette et al. 2008; Ravindra et al. 2009) and imitation therapy (Bird et al. 2007; Duquette et al. 2008). However, the study on using humanoid robots to improve the emotional wellbeing of autistic people has not been explored yet. Considering the limited human attributes and constrains of the range and level of emotional engagement with human partners provided previously. This paper aims to influence emotional wellbeing of person with autism in terms of developing reciprocal relationship and making them more productive and useful to improve their impairments in social skills, communication and imagination.

A continuously field trial in Australian family to help person with autism has been undertaken. After data collection, the analyzed results demonstrate that the long term benefits of using robot with autistic people can maintain through maintaining the service novelty and personalization. The trials design lifestyle centred robot enabled services underpinned in persons with autism. The integration of service delivery includes human-like communication attributes like voice, emotive expressions, head and body motion in dancing style to generate positive emotional engagement of the person with autism and breaking technology barriers. The robot embodiment provides flexible interaction modes using voice, touch panel and/or face involving cloud computing and computer vision techniques to meet disability needs and comfort requirements.

The structure of this paper is followed by literature review. Section 3 outlines the research methodology. Section 4 demonstrates research findings and outcomes. The last section discusses and concludes this paper.

II. LITERATURE REVIEW

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.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.

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 autism. 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).

III. RESEARCH METHODOLOGY

Our research is different from existing work in the following aspects: First, most of existing work focused on using robots as therapeutic or treatment tools to improve impaired skills of the children with autism in a community or a school based environment. We have 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) in a home-based care environment. Secondly, the research on therapeutic-assisted robots was conducted in short therapy sections or classroom environments. We have conducted a longitudinal trial with young people with autism in a home-based environment and this is the first ever Australian home-based care trial. The participants have willingly spent hundreds of hours interacting with the Humanoid robot (Lucy). Additionally, social assistive robot 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 autism.

A. Lucy - A Socially Assisitve Communication Robot

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.

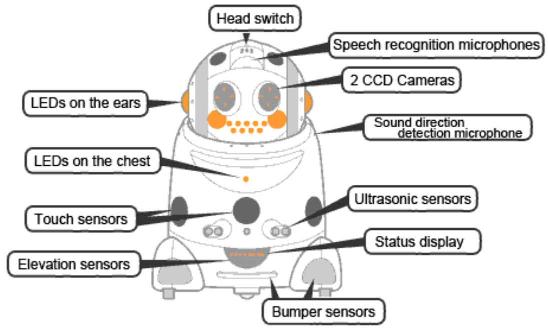


Figure 1: Lucy's specifications

The field trials have been designed with the aim of evaluating the impact of Lucy in the context of Australian home-based autism care involving 25 year old male adult and 23 year old female adult with autism. The impact is determined in terms of positive engagement, usefulness, frequency of interaction with Lucy. The results and findings in this paper relate only to the interactions of 25 year old male adult with Lucy. In this context the robot service design methodology is outlined next.

Theoretical Foundations of 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 and emotion recognition) and cloud computing based communication techniques (e.g., using tablet and touch pads to give instructions to Lucy) .

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.

The embodiment of interactional environment in Lucy involves modeling of human characteristics like gesture, emotion and expressions, voice, motion and dancing and dialog adaptation in design of various services delivered by Lucy. The subjective experience in an autism care context involves design of services personalized around the lifestyle of person with autism. These lifestyle based services which reflect their personhood should enable a reciprocal relationship between Lucy and the person with autism and consequently make them more productive and useful (Goetz and Kiesler 2002). The need for engagement, reciprocal relationship and usefulness is relevant in a home-based care environment where assistive technologies need to support the carers by the persons with disability partially independent for limited periods.

Interacting 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).

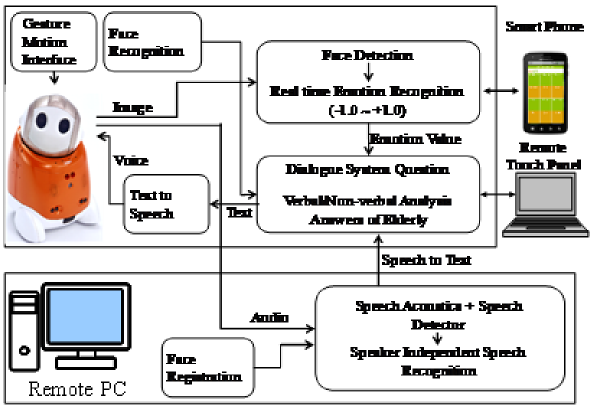
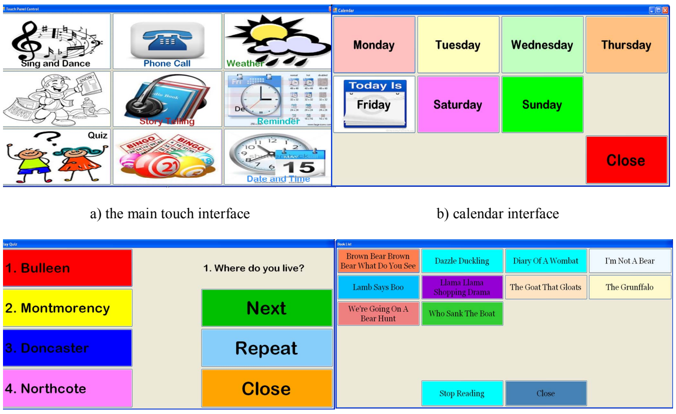


Figure 2: Lucy and its components

Lucy can communicate with them using voice vocalization and speech recognition, face recognition and activation, and through visual display in touch panel. For this reason cloud based computing, computer vision and speech recognition techniques have been used. In this trial, the participants have used touch panel as shown in Figure 3.



a) the main touch interface b) calendar interface

c) Quiz interface d) book list interface

Figure 3: Touch panel interface used in the trial by people with autism

B. Modelling Services for Measurement of Constructs

Table 1 shows the mapping between subjective experience and emotional wellbeing constructs (Health, 2010) and corresponding services designed to be delivered by humanoid robot to person with autism.

TABLE I. CONSTRUCTS AND SERVICE DESIGN OF ROBOT

Subjective Experience and Emotional Wellbeing construct	Lucy's services
Positive Emotional Engagement Sensory Enrichment Reciprocity	- Sing and dance - Reading books - Telling news
Social Connection	- Game (Bingo) - Phone calls - Skype
Needs and Comfort	- Flexible communication modes (e.g., voice, touch panel)
Productivity and Usefulness	- Quiz system - Reminder

C. Data Collection

Each log data has been collected and the entry of activity log files contains <entry id> <id of recorded video> <Date> <Time> <Name of accessed service>. When the participants interact (using Touch Panel) with robot, video recordings are activated using two eyes (cameras) of the robot. The videos are time stamped and labeled according to the service uses (i.e., a recording 'sing_2013_11_29_10_17_36.avi' means the video was recorded during singing and dancing at the time of 10:17:36 on the date 29/11/2013). The label of the video assists the analyst to analyse service-based engagement of the participants while the timestamp is used for analysing service patterns and frequency of service use. The social attitude and engagement of the participant is recorded for each activity during the first five-minute interaction. Meanwhile, the carers also submit their feedback in written form. The feedback is then analysed and mapped to relevant constructs of robot which finally consolidated with the video observational analysis.

D. Service Design

According to the pre-determined constructs, the service design is elaborated in context of sing and dance, interactive storytelling and quiz activities in this section (figures 4, 5 and 6 respectively).

Sing and dance:

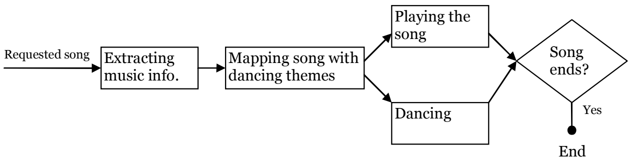


Figure 4: Flow chart for playing a song

Book Reader (interactive storytelling):

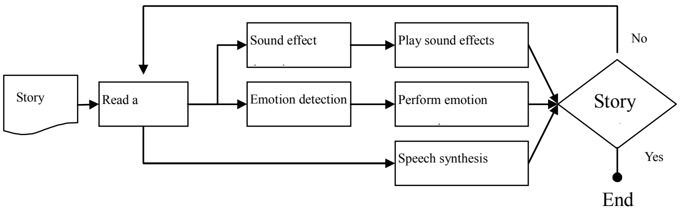


Figure 5: Flow chart for interactive story telling

Let s be a sentence and w_s an emotion label. Let e be a set of m possible emotion categories (excluding neutral), where $e = \{e_1, e_2, \ldots, e_m\}$. The objective is to label s with the best possible emotion label w_s, where $w_s \in \{e_1, e_2, \ldots, e_m, neutral\}$. We follow the classification found in WordNet-Affect. This is an extension of the WordNet database [5], including a subset of synsets suitable to represent affective concepts. Starting with WordNet-Affect, we collected six lists of affective words by using the synsets labeled with the six emotions considered in our data set. Sentiment analysis and the recognition of the semantic orientation of texts is an active research area in the field of natural language processing (e.g., [17, 12]). A crucial aspect is the availability of a mechanism for evaluating the semantic similarity among "generic" terms and affective lexical concepts. In particular we implemented a variation of Latent Semantic Analysis (LSA). LSA yields a vector space model that allows for a homogeneous representation (and hence comparison) of words, word sets, sentences and texts. For representing word sets and texts by means of an LSA vector, we used a variation of the pseudo-document methodology described in [1]. In practice, each document can be represented in the LSA space by summing up the normalized LSA vectors of all the terms contained in it. Thus a synset in WordNet (and even all the words labelled with a particular emotion) can be represented in the LSA space, performing the pseudo-document technique on all the words contained in the synset. In the LSA space, an emotion can be represented at least in three ways: (i) the vector of the specific word denoting the emotion (e.g. "anger), (ii) the vector representing the synset of the emotion (e.g. {anger, choler, ire}), and (iii) the vector of all the words in the synsets labeled with the emotion. In this paper we performed experiments with third representation. Regardless of how an emotion is represented in the LSA space, we can compute a similarity measure among (generic) terms in an input text and affective categories. For example in a LSA space, the noun "gift" is highly related to the emotional categories joy and surprise. In summary, the vectorial representation in the LSA allows us to represent, in a uniform way, word, sentences or emotional categories.

If similarity is defined between a given input text (i.e., sentence), s, and an emotional class, e_j, as $sim(s, e_j)$, the emotion label w_s of s is more formally represented as follows:

$$w_s = \begin{cases} \arg\max\left(sim(s, e_j)\right) & if\ sim(s, e_j) \geq t \\ neutral & otherwise \end{cases}$$

Where $sim(s, e_j)$ is computed as cosine:

$$sim(s, e_j) = \frac{v_s \cdot v_{e_j}}{\|v_s\| \cdot \|v_{e_j}\|}$$

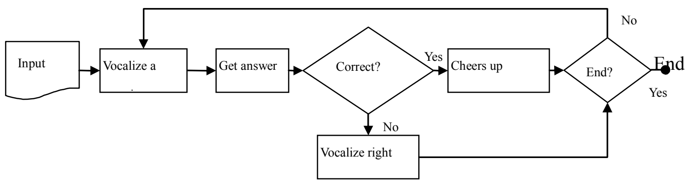


Figure 6: Flowchart for hygeine quiz

The quiz is designed to assist the human partners improve their cognitive ability, teach them basic knowledge and basic routines (sequence of actions) they need to follow in daily tasks (i.e., the question "When I have been to the toilet and I have pushed the button and washed my hands. Then I need to" has three options (right one is underlined): 1. Leave the bathroom; 2. Dry my hands; 3 turn off the light" has been used to teach the participants a sequence of actions they need to do before leaving the toilet).

IV. Findings and Outcomes

In this section authors focus on findings and outcomes related to 25 years old male adult with autism only. One of the main concerns of parents of the male adult with autism was his inability to learn proper toilet hygiene habits.

A. Breaking technology barriers evidenced through frequency of interactions

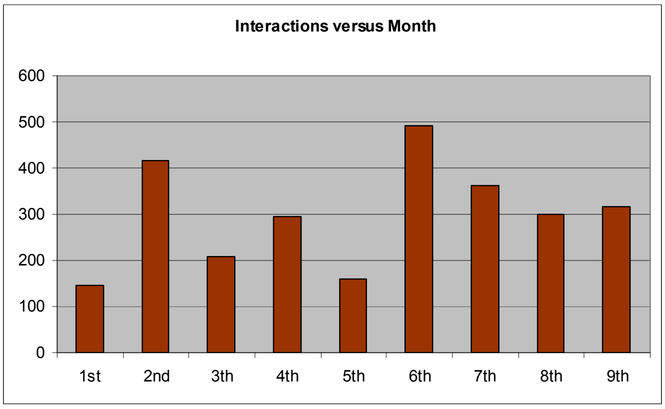


Figure. 7. Frequency of interaction

We analyze the requirements of young people with ASD from the perspective of facilitating acceptability of Lucy as part of their environment in their daily basis based on interviews with domain experts, their care givers and parents. All of the participants would like Lucy sings their favorite songs, dance for them and read their favorite books. By socially engaging the people with autism with Lucy through familiar activities (e.g., singing and dancing to favourite songs and interactive storytelling) which they are doing in their daily life, we are able to break technology barriers and encourage acceptance of Lucy as shown in Figure 7 through high frequency of interactions with the young person with autism.

B. Benefits of service personalisation (adaptation) evidenced through increase in engagement

The ability of Lucy to design and update and adapt personalized services and deliver the services in a believable manner through use of emotive expressions and sound effects (adapted based on dance themes and story text (with emotive words, animal sounds, etc,), voice as well as head and body movement result in increased engagement and service use. Based on the log data collected, Figure 8 shows spike in song and dance and interactive storytelling (book) service usage in 2nd, 6th and 8th month respectively.

Additionally, one-to-one activities like Lucy reminding people with autism about their calendar of activities for the day are other services which have designed to make people with autism feel more useful and resilient. Figure 9 shows an hour wise interaction breakdown of services.

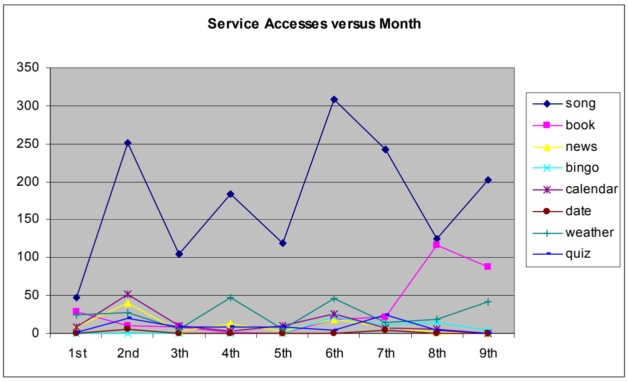


Figure 8: Increase in service usage through service personalisation.

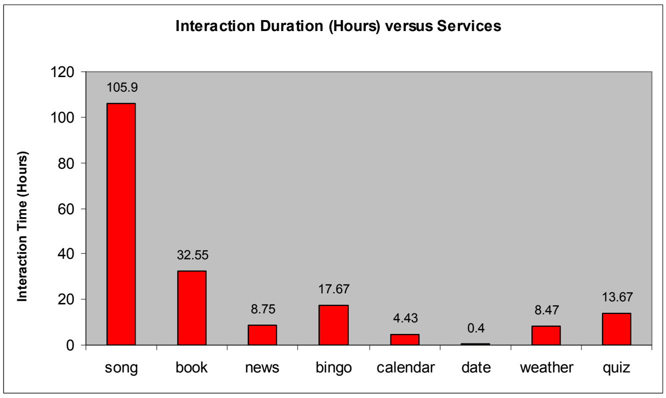


Figure. 9: Hour wise Interaction

C. Sense of Usefulness through Mental Activity with Robot

Playing quiz with Lucy has positive impact on mental activity and sense of usefulness to the children with autism. The quiz consists of 10 questions has been written by the children' 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. 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.

The statistics from the log data show that through prompting and vocalizing the right answers to the children, they can learn basic knowledge which helps them in their daily life. This is indicated by the improvement in the quiz performance of the participants (Figure 10). One of the parents comments out that their kid remember to "turn of the lights" and "wash their hand" before leaving the toilet.

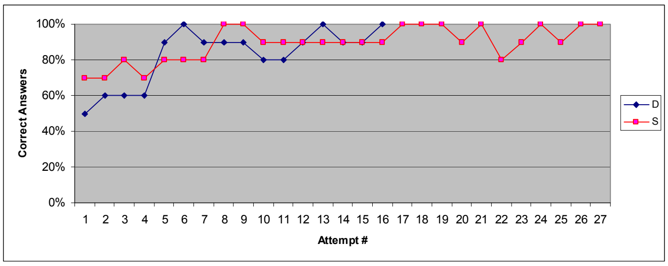


Figure 10. Quiz performance

In addition, with the help of calendar reminder, the participants become more independently from the parents or care givers since they can know when they need to do their simple basic things (i.e., going to the bed, waking up in the morning, drinking a cup of water, help their parents to get the washing of the line, etc.).

V. Discussion and Conclusion

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 (sample interaction video attached). In addition, the results of this study indicate that the human-like characteristics in combination with personalized service design facilitate the acceptability of Lucy to young people with autism; the trial participants 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 children 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 the participants 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.

In this paper, we have represented the outcomes on the first ever 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 have in daily lives of young adults with autism have been realised. Multiple sources of collection of data including interviews, video recordings and non-verbal (emotional response) data recordings 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 which has been going on for more than 3 months has provided respite to the parents. In future, we are adding new services and enhancing existing ones (e.g., quiz, reminder and singing) to make persons with autism be more productive. The research results show that by marring the embodiment of care in combination with artificial intelligence, emotion measuring techniques and positive emotion engagement in its design, Lucy has successfully eliminated the barriers of use of technology by people with autism, and more importantly has had a positive impact on their emotional well being, contributing to enhance their quality of life.

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