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Inclusively Designing for People in Human-Robot Collaboration

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Abstract. This article offers the perspectives of adults with intellectual disability on how future trends, particularly in social robotics, but also in collaborative robotics, can be co-designed inclusively. These perspectives are offered through research findings as well as researchers' reflections from co-design and exploratory projects where the research team has engaged adults with intellectual disability in formal and informal learning activities led by social robots. We propose that future work can adopt the social model of disability and a human-rights approach to inclusive technology design by positioning research in a way that respects people's unique interests and competencies, understands the role of support networks, and engages with communities that celebrate human connections. We provide practical insights into inclusive research approaches and considerations for protocols that meet the requirements of the Australian National Statement on Ethical Conduct in Human Research.

Keywords: inclusive design, intellectual disability, social robots, assistive robotics, social model of disability, human rights, co-design.

1 Introduction

People with intellectual disability are largely overlooked in the literature on assistive technology, representing only about 2% of papers published [16]. Most of the literature around cognitive support focuses on children with autism [22], and most papers investigating robots to support people with intellectual disability investigate the role of social robots for rehabilitation [26] or education [18]. As the field of assistive robotics develops, it is essential to make sure that adults of all abilities are considered in the design of robots that can collaborate with people who require support to work, live, move and learn.

Researchers in Human Computer Interaction and Assistive Technology have transformed methodologies and approaches in recent years to move away from a medical model of disability to a Human Rights approach. This means focusing on people's strengths, respecting their wishes, and engaging in participatory approaches where end users have a say in what the technology should achieve and how it may (nor may not) support them.

This paper contributes an integrated perspective of how the last 10 years of developing co-design methodologies for technologies supporting people with intellectual disability can be considered in collaborative and social robotics. We present 3 examples of how we have applied the principles of respectful and strengths-based approaches to study design opportunities for social robots that operate in non-dialectic ways, such that they leverage collaboration, recognize individualities, and integrate the role of support networks. We argue that collaborative design methods and features are the key to maintaining people's dignity and can support long term engagement. We conclude the paper with a practical guide to methods and ethical study setup to support more robotics researchers to include adults with intellectual disability in their designs.

2 Background

The first author of this paper has started co-designing with adults with intellectual disability in 2012, has spent 5 months volunteering in disability services of an organization supporting adults with intellectual disability in 2015, and conducted studies regarding a range of technologies such as mobile applications, virtual and augmented reality, communication technologies, and social robotics. Most of her work has been in partnership with the same organization located in Australia. She has co-supervised students who conducted studies in Sri Lanka, Pakistan and Ghana.

The work referenced in this paper has been conducted in partnership with a disability service organisation in Australia [4, 18, 3]. The organisation supports adults with intellectual disability through day centres where people participate in community-based learning activities, which include both formal and informal learning. Formal learning may include health literacy or communication, while informal learning occurs through activities such as museum visits or technology workshops. The research we have conducted with adults with intellectual disability in this context was exploratory in nature. The activities with the robots were discussed ahead of time with managers from the organisation and amongst the research team, and iterated through ongoing reflection, both in-between the workshops and during the workshops themselves. All research activities were conducted under a protocol approved by the QUT ethics committee (approval 1400000673), and easy-read consent forms were provided to participants as well as ongoing reminders of the voluntary nature of their participation in the research. One of our former research participants, Chloe, has now joined our research team to provide lived experience on our research direction. In her first research paper, she reflect on how robots could support people, as well as the significance of participating in technology co-design [13].

In 2023, we started a new format for our research activities, informed by the Techshop approach [7]. We have invited adults with intellectual disability to attend technology workshops at our University Campus, for 2 hours every week or every second week. Participants attended in groups with one support worker for every 4 participants. A total of 39 adults with intellectual disability and 15 support workers have attended at least one of the workshops. We covered a wide range of activities during these workshops, and will provide some reflections here on those that involved robots such as Pepper, Cozmo, Miko, Dash, Cu or Alpha Mini. All participants in the workshops have provided consent to be observed, and most have provided consent to be video recorded, in line with a protocol approved by the QUT ethics committee (approval 2000000213). Additionally, since 2023 and under the same ethical clearance, we conducted exploratory studies on how robots could support employment. We first observed 24 people in 6 work environments (including hospitality, manufacture and administration), then conducted interviews with 4 workers and 4 work managers. However, in this paper does not aim to discuss in details the findings of these studies, which are still under review or in Press at the time of writing. We will draw some illustrative examples from these studies and reflect on them from the perspective of published findings we are reporting on.

Fig. 1. Use Case: setup with social robots in a workplace

Use Case: Ongoing study in supporting employment

We will use an ongoing study of social robots in e-recycling workplaces to illustrate the principles of study design presented in section 5 and practical steps presented in section 6. This use case presents elements we have already incorporated in the study, however the outcomes and findings of the study are beyond the scope of this article and will be published after the study concludes. In this study, the focus is on social robots that afford interactions in a range of modalities to create more inclusive experiences for people with intellectual disabilities in employment or volunteering (employment-like) environments. It involves co-designing through iteratively designing, trialing and reflecting on exploratory prototypes of robot applications deployed as in a employment context.

Use Case: Methodology

The practical use case is a 6-weeks study in e-recycling facilities with iterative versions of a prototype application on the Pepper robot, which we describe further in the paper as a case study. The study consisted of trials of iterative prototypes of applications designed for the Pepper robot. Some applications were already built and included in a panel of applications that participants could select from (for example, jokes or dances), while others were programmed for the study. The robot's applications were trialed one day a week for 6 weeks in 2 different locations where people disassemble electronics, such as presented on Figure 1. All interactions were video recorded, interviews were conducted with workers and site managers. The researchers took notes and debriefed collectively after each session. The prototype applications or the proposed activities were refined every week based on the debrief.

3 Dignity By Design: Key Learnings From Codesigning Technology With People With Intellectual Disability

We provide a brief overview of some context relevant to technology researchers in order to position their work as respectful collaborations with people with intellectual disability. Further elaboration of this context can be found in the introductory chapters of an extensive review addressing the information retrieval research community [28].

3.1 Intellectual Disability and Technology

There is often a confusion between various cognitive disabilities, partly due to a lack of knowledge and partly due to language that evolves differently in different part of the (English-speaking) world. For example, while autism can have a concurrent diagnosis of intellectual disability, it does not necessarily imply the latter. Intellectual disability is not a medical diagnosis but a functional diagnosis, which means that it is assessed based on impact on peoples' day-to-day functioning. With that in mind, it is best to determine peoples' experience based on the support they receive or require. For example, people supported in group day activities generally need support with learning, with some day to day activities, and may or may not be verbal. They may require support because they have difficulty remembering task sequences, understanding instructions, manipulating small objects, abstracting processes required in day-to-day living, or regulating emotions. However they are able to (and enjoy!) interact with other people, can follow simple instructions and answer simple questions, walk in a known space, create and appreciate artwork. Common associated clinical diagnosis are down syndrome or lack of oxygen at birth, however these clinical diagnosis do not indicate people's ability to live, learn, travel or work independently. Similarly, measures such as IQ do not provide any indication on people's support needs, which are what is relevant when we consider assistive, inclusive or accessible technology.

Engaging with technology requires a number of cognitive skills, which can include language abilities (understanding or producing), process and sequence memory, short-term and long term memory [31]. Assistive technologies are intended to bridge a gap between demands of society, non-accessible technologies or environments, and people's abilities. Accessible technology is either compatible with assistive technology (eg. web pages that meet standards for screen readers), or universally designed (natively accessible by all). Inclusive technology seeks to promote the inclusion and participation of people of all abilities, and is the responsibility of society to promote and create. Robots, if well designed and accessible, can play a role as both assistive and inclusive technology. In this paper, we will focus on the inclusive aspects and approaches to promote inclusion through design.

3.2 Co-Design Philosophies

Co-design approaches, which are a form of participatory design, emphasise the role of "end users" in not only informing design, but also setting a political agenda for what new designs should address. People with intellectual disability are the experts of their lived experience [11], and are not only "end users" of technology but can also be affected by technology deployed in the community, in their homes or in their workplaces. Co-design is often understood through the lens of the co-design workshop methodology, often employed at the launch of new participatory projects, and where a range of stakeholders are brought together with stacks of post-it notes in order to brainstorm and ideate issues to address and possible solutions. In technology co-design, innovative approaches have employed technology cards and prototyping tools in order to engage participants in co-creating technologies. For example, researchers have used drawings of participants' homes and sensors to elicit role of robots in the homes of older adults [14], and basic shapes and abstract objects to provide hands-on opportunities to people with dementia to co-create the visual appearance of support robots [19]. They also used interaction and modality cards to support participants in exploring what the robot could do [19].

While technology design is often a process associated to solution to particular problems, alternative frames such as experience design are instead shifting the focus on improving people's experiences [17]. Approaches such as digital ethnography, contextual inquiry and rapid-agile iterative design enable both designers and participants to focus on contextually relevant experiences. These approaches are also particularly suited to participants with intellectual disability, who can best express their views on a technology design by engaging (or not) with various parts of a working prototype they are presented with [29, 12].

In order to best engage participants with intellectual disability in the design process, the co-design activities need to support their diverse ways of expressing themselves with appropriate tools [25] and in a respectful manner [21]. As a result, while iterative working prototypes are a starting point, these should be sure to embed features that support self-expression, as per the "self-expression by design" guidelines [36]. Such features may be in the form of drawing pads, cameras, or voice-recording, that should be embedded within prototypes.

3.3 Competency-Based Design

In the previously outlined co-design philosophies, making sure that participants with intellectual disability have a say through diverse modalities and within context that are relevant to them is key. Here we highlight another key philosophy, which guides how technology and interaction designers may leverage people diverse competencies for embedding accessible features into their prototypes, termed competency-based design [6]. Competency-based design consists in creating opportunities to observe people's existing competencies, creating prototypes that can help reveal people's competencies, and finally designing features that leverage these competencies.

Competencies that can be observed through digital ethnographies are highly reliant on the opportunities that people have been given by their support network or their circumstances. For example, someone who does not own a mobile device may not have had the opportunity to learn to use a touch screen. In previous research conducted in Sri Lanka on web access, participants never had the opportunity to use Internet before the research took place [1]. Observing competencies in this context becomes a reciprocal learning activity, where the participants can learn about technology from the researcher while the researcher learns about people's competencies and interests with regards to technology. This approach was formalized through the "Techshops" approach [7]. This approach is particularly relevant to robotics, where it would be rare for participants to have had previous experience with specific emerging technologies.

Designing with competencies is akin to the ability-based design philosophy [37]. Ability-based design was developed to shift the narrative for assistive technology, specifically for people who are blind or have low vision. The premises is that if we try and design to replace what currently requires sight in existing technology, it suggests that we seek to minimize the efforts of a system to adapt and leave the onus to people to use systems not designed to their particular circumstances. Instead, by emphasizing people's abilities, for example to understand very rapid speech that builds on keywords, new ways of designing for this particular modality first can emerge. In a competency-based design approach, instead of seeking a form of universal ability that would be shared by a cohort of people, we seek abilities that people may have developed in certain contexts, either because they were highly motivated, or because they have seen others use it [30]. An example of such a competency was visual browsing, in which we saw a non-verbal participant develop in order to access his favourite videos on a web-based video platform [10].

3.4 Implications for Inclusive Robotics

Considering inclusion and participation before support, and seeking people's competencies a primary material for starting design, we are proposing an approach to inclusive robotics that preserves dignity and places robots not as an agent of replacement or support, but as a collaborative entity that respects and honors its human collaborators.

The first implication of this new positioning is that robots should not replicate what people can already do, and take away mundane tasks if this is what they enjoy doing. In our Techshops, participants suggested that robots could help them with

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grocery shopping or withdrawing money at the bank, highlighting parts of the tasks that the robots could help them with (remembering steps or carrying products) as well as companionship, but none of their suggestions was to send the robot to operate fully on their behalf. For example, ”P9’s robot was designed to help him in the kitchen. He said that it moves fast like ‘Bumblebee’ from the Transformers movie. It has a humanoid head and can talk. The robot would explain steps for preparing recipes and would act as a cooking assistant. It can pick up and hand items to P9” [5]. This is particularly relevant in the manufacturing sector, where replaced “dull” jobs may be the same jobs that people with intellectual disability thoroughly enjoy because they can achieve concrete outcomes with no ambiguity, and with easily accessible repeated instructions if they require. This highlights the importance of conducting inclusive studies when considering the role of robots or collaborative robots in workplaces. If engaging only with people who are already in the workforce, designers could end up reinforcing the exclusion of workers with intellectual disability rather than using the technology to create new work opportunities for them.

Use Case: Not replicating what people can already do

The robot application we designed was intentionally not attempting to operate the dissassembly tasks that people are doing. Instead, it focused on connecting workers socially.

The second implication of this positioning is that robots should support people in achieving more or with more confidence. Connecting more with people around them, having more agency in their day-to-day living, working more effectively. In our studies in work environments, participants often highlighted a desire for companion robots that could provide reminders of tasks sequences or help them with decisions or quality control would provide additional confidence in their work tasks. Offering robots as tools that can help people achieve more, rather than asking people what robots could help them with, is an important distinction that can be critical for people who are proud of the independence level they have achieved and ensure that their dignity is preserved when exploring how their independence could be further supported. The support may go beyond practical aspects, for example, Chloe highlights in her paper how Technology may ” give family carer peace of mind for short outings knowing that their loved ones are going to be OK ” [13]. The outcomes of a technology intervention may not be binary, or economical. For example, empowering people in doing their own cooking may still also require some human support, and take more time than having someone else cook, however this is an important aspect of people’s self-esteem and self-actualisation.

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Use Case: Achieving more with more confidence

A sorting application was developed to enable participants to show an item and hear and see where it should be sorted. The visuals were of coloured boxes, and the same colours were placed on the actual boxes to sort the materials.

The third implication is that robots may be side-kicks, with a cognitive rather than/in addition to a practical purpose. ”Technology would be something that I would probably say, if people don’t have the confidence to want to speak to any of us or any support worker, then I would probably recommend starting it with maybe a talking app or you can go Pepper.” A social presence is critical to providing cognitive support, which can take the form of hosting knowledge, diffusing attention (eg. in conversations), or prompting. A side-kick gives greater confidence but does not steal the show, and as such robots as side-kicks have the potential to support agency and participation both in day-to-day learning and living, but also at work. It is particularly critical in the work arena, as many people wish to work in hospitality, but don’t always feel confident about engaging in direct conversations with clients. People from our study in work environments who worked in hospitality were often seeking interactions with clients. However, they also not always confident about fully understanding their orders, or knowing how to continue conversations. Other client-facing tasks, such as museum guidance or peer-training may require memorising facts that social robots can provide, while people can offer their personal insights to attendees.

Use Case: Side-kicks, with a cognitive rather than/in addition to a practical purpose

In addition to the sorting application, a ”Pack up time” application was developed for the robot to encourage everyone packing together at the end of the day. The application consisted of a song and movement, and in this instance was not interactive nor personalised. It was designed to get everyone on the same page through the robot.

4 A New Narrative for Inclusive Robotics

If robots, particularly social robots, will be making their way into support scenarios, a new narrative of connecting, engaging, and gaining agency will ensure that they are doing so in a way that also supports inclusion, not only independence or functioning. We present reflections on how three studies we have conducted with commercial social robots in the past 5 years shed a light on inclusive aspects of designing interactions with social robots.

4.1 Beyond Dialectic Interaction

Social robots, like mobile applications and conversational agents, tend to be conceived and designed for dialectic interactions: one person interacting with the robot/agent, in turns. As a result, the benefits and outcomes tend to focus on the betterment of satisfaction of the individual user: how much they have learnt, engaged, enjoyed, produced, moved etc. This fits really well a narrative centered on the medical model of disability, with research seeking how social robots can help

Fig. 2a.. Participants connecting through the Cozmo robot

Fig 2b..Participant controlling the Cozmo robot

children with autism improve their social interactions, or how they can improve the independence of older adults to age in place. However, this is counter to a human rights model that seeks inclusion. While social robots can serve as companions, it is important to not create a new narrative where we can leave people alone and replace human company and contacts by robots.

In early 2019, we conducted a series of 5 workshops with small groups of participants as they engaged with the small social robot Cozmo by Anki[4]. We were interested to explore what the robot could offer in the context of communitydriven day activities ran by a disability service organisation, how the robot may operate with more than one person at a time, and how engagement would continue beyond the novelty effect of the first encounter. As an exploratory study, the activities were proposed to participants, but they were also able to take the lead on how they wanted to engage with the robot.

The proposed activities were guided by both the progression that the companion application of the robot offered and by our reflections after each workshop. Some of the 6 participants took part in all of the workshops, while others left early or joined later. Some activities were designed as competitive games and required participation of 2 people at the time (see Figure 2a). Other activities, involved taking turns to interact individually with the robots. Some individual activities, such as ”feeding” the robot with energy from the accompanying cubes, were lending themselves to turn taking within the activities while others, such as remote controlling the robot (see Figure 2b), were lending themselves to a single turn where participants could interact with others through the robot's actions (making the other participants laugh, having the robot tell them something, etc.).

The push to look beyond dialectic interaction is well aligned with the principles of self-determination theory [24], which were apparent throughout the study. Self-determination theory posits that satisfaction from technology emanates from a sense of autonomy, competency and relatedness and was particularly developed in the context of video games [35] but also human-robot-interaction [15]) . While the quality of the animations and anthropomorphic features of the robot clearly played a role in engaging participants, the sustained engagement more likely emerged from the opportunity for the robot to foster interactions between participants, meeting the relatedness intrinsic needs of our participants. This was particularly salient when one of the participants found herself alone in her group and went to recruit a new participant from the centre (relatedness). She then proceeded to demonstrate to the new participant what the robot can do (competency) and demonstrated how it can be remote-controlled for movement and language (autonomy).

Use Case: beyond dialectic interaction

The robot was placed in an open space in the workshop, enabling people to join in the robot-led activities as a group.

4.2 Understanding Diverse Styles of Engagement – Responses to Social Robots

When we generalize preferences or behaviours across cohorts or organised by demographics, we run the risk of leaving behind in our designs flexibility for different ways that people engage, and to conceal this from our research results. For example, researchers (including ourselves) may use age as an indication of whether people are “digital natives” and assume different behaviours. However, we have

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found in our fieldwork that some older adults very engaged and interested in social robots, while some younger people who were regular players of video games were very disappointed by the commercial social robots we presented to the point of disengaging entirely. It is helpful to not only acknowledge that robotic solutions may not suit everyone, but also, and particularly for robots with social features, that there is a range of emotional and behavioural responses to consider.

In late 2019, we conducted a learning activity guided by the social humanoid robot Pepper (then developed by Softbank Robotics) with 3 groups of participants, totalling 11 adults with intellectual disability and 3 support workers [18]. The activity was blended into existing learning programs that were offered as part of community-driven day programs offered by the partnering disability service organisation that supports the participants, and the goal of the research was to explore how the social robot could promote engagement while delivering learning

Fig 3a.. Participants connecting through the Cozmo robot

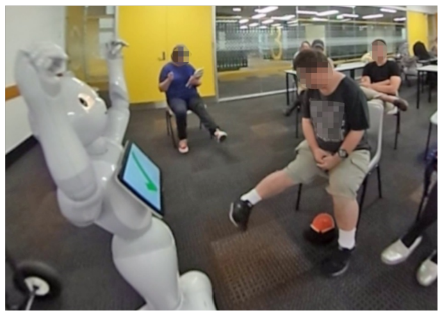

Fig 3b.. Participant controlling the Cozmo robot

content. The robot was not programmed to use the camera for face recognition (for privacy reasons) or the microphone (for reliability reasons), and was therefore not able to converse with participants. It was however able to track people interacting and display a behaviour of fixating people, with the eyes turning pink when locking onto a participant.

A key takeaway from the study was that participants with intellectual disability engaged with the robots in very different ways, which did not correlate with their abilities. Participants' abilities varied in terms of verbal expression, length of attentive focus, and their ability to answer questions about learning content. Independently of their abilities, some of the participants exhibited "high intensity engagement and emotional attachment", such as shown in Figure 3a, seeking to hold the robot's hand and addressing it as a person. Another subset of participants exhibited an "intermittent focus" behaviour, which could also be attributed to an unfamiliar environment for the research taking place. Some other participants exhibited a ”quiet and obedient” demeanour, such as shown on Figure 3b, following instructions by the robot or the session coordinators but not seeking additional contact with the robot either verbally or physically. Finally, some of the participants were simply not interested in engaging with the robot, regardless of their ability to engage with the learning material itself. These variations between participants, in addition to the broad spectrum of abilities and interest they display, means that quantitative or comparative studies cannot be leveraged in this space. Similarly, cohort-based studies that would not recognize these important variations in attitudes would not be able to measure any potential benefit for robots. Instead, we recommend acknowledging this diversity with methods that approach important questions qualitatively, also recognizing the interpretive elements that such approaches suppose [33].

We have continued to observe this range of behaviours and responses to the Pepper robot in subsequent studies, which are still under review. While this first study was only engaging with young adults between 20 and 30 years of age, the range of attitudes remained equally spread when we engage with participants up to 60 years of age. This study confirmed that participants who exhibited a ”quiet and obedient” demeanour were in keen to continue to engage with the robot over time and that this behaviour was not a mark of lack of interest. ”High intensity engagement and emotional attachment” were expressed in a broader range of manners, with some participants voicing joy and others articulating futures where Pepper would be their daily companion. We have encountered 2 participants who were not interested in meeting Pepper again after a first introduction. Both of them shared with the research team that they were finding the robot too basic, and they would like it to be more like robots they have seen in video games they play. Both these participants were in their early 20’s and were avid video game players.

Use Case: Recognising Different Styles of Engagement

The frequency and type of engagement with the robots were not prescribed in this study. Participants could chose when and for how long to engage with applications. They were able to engage with the prototype applications, but could also request other applications designed for entertainment, such as robot dances or jokes. The location of the robot within the main workshop enabled people to engage indirectly with the robot, for example observing it from a distance as other participants engaged. It helped some participants build confidence overtime, and we saw some participants starting to directly interact with the robot after 6 weeks.

4.3 Design With and For Support Networks

Another consequence of a focus on dialectic interactions is that usability and accessibility are only considered from the perspective of single user. Yet, the ability of the robot to both support agency of adults with a disability and support that can be provided by peers or support network is a key aspect of how they can improve people's lives.

Incorporating the role of multiple stakeholders in the design of interactions with robots add nuance to the concept of accessibility, and opens up new designs where some interactions are fully accessible while others may be accessible through support. Previous research [27] proposed a similar shift for information access behaviours, incorporating support as part of the information retrieval model. This model also means that robots can have a role as enhancing users' experiences, rather than solely seeking independence for users who can operate the technology by themselves. An interdependent approach, in line with broader models of interdependence [8, 34], in contrast, can give members of support networks more time to engage on a human level, and people with a disability more agency to chose what the technology provides them with. In the example of our study with Pepper [18], the support workers highlighted the potential that the robot delivering the knowledge and engaging participants in learning meant they could focus on supporting participation in the learning activities.

Table 1. What support workers value as proxies, and as users.

Values as a proxy	Values as a co-user
Perceived value to users	Support worker's personal interests
Ease of use for people with intellectual disability	Technology as a tool to help their job
Interests of people with intellectual disability	Competencies of support workers

Additionally, adoption and use relies on support networks. One year after our first study with Cozmo [4], we returned to the centres that had Cozmo robots available and that had been very enthusiastic about its potential to engage people in meaningful activities for a long time. Yet, the robots were gathering dust on a shelf and no activities were leveraging their capabilities. Through a value-sensitive design approach, this research [3] demonstrated that the lack of adoption was emerging from conflicting values of support workers in their roles as proxies for the people they support and their roles as professional workers. Table 1 summarizes the values that drive their decisions and technology practices in each of these roles. In their roles as proxies, they valued the engaging and educational potential of Cozmo, and we enthusiastic about its ability to be a highly fun activity for people with intellectual disability. In their roles as professional workers, they were finding it difficult to find the time to learn the technology, if it was not something they were otherwise already passionate about or interested in.

Use Case: Design With and For Support Networks

Job coaches, support workers and site managers were present and welcome to interact with the robot throughout the study. They often offered their perspectives after observing workers engage with the robot. We also interviewed them throughout the study, and asked their perspective on how robots modify the work environment, enhance their role in supporting the workers, and what benefits and risks they were seeing.

5 Practical Steps Towards Social Robotics Inclusive of People with Intellectual Disability

Positivist approaches (quantitative studies or qualitative studies seeking a "representative" cohort and generalization) don't lend themselves well to research that can shed a light on people's experiences, and the nexus of people, context and technology. The case studies we have reflected on in this paper all illustrate the importance of individual experiences, values and preferences, the influence of context and ways to create new conditions for successful engagement that become inseparable from the technology itself. Instead, we advocate for methods that are situated, collaborative, and personalized so that we can focus on people's strengths and offer support as required. The outcomes will not be onesize-fits-all design guidelines, but ideas, questions and considerations for people who build and deploy robotic technology. These approaches are more broadly valid to create engaging and lasting collaborative experiences in most contexts, and we present some practical steps to support the participation of co-designers with intellectual disability.

For social robotics to become more inclusive of people of all abilities, we need both methods that can integrate with existing research and approaches, as well as methods that can specifically address the unique perspectives of people with a disability. Co-design methodologies such as those introduced in section 4.2 lend themselves well to placing research participants first, but the principles can also apply to quantitative methods that are often task-based, as part of a mixed methods approach. Often the qualitative elements, not only about how people interact with a robot, but also how to setup the research itself, are more valuable than the quantitative findings to move forward. We will focus on qualitative approaches here, and discuss ways that controlled studies can be conducted in more inclusive ways in section 6.2.1.

5.1 Human-Centered Positioning

Human-centered approaches employ methodologies that are iterative, exploratory, reflective and ethnographic. These approaches can ensure that the agency of participants is preserved. They support a narrative that is not focused on improving people's ”conditions” or autonomy, but instead seeks to discover ways to improve people's experiences, through technology that fosters inclusion. Experience design explicitly excludes problem solving approaches and, and explores context in depth instead [17]. Such approaches are often counter-intuitive for people trained in engineering and robotics, as engineering approaches typically identify problems and seek the most effective/efficient solution, often framing people as part of the problem itself! However, inclusion is experiential and will carry the complexities of human relations between each other as well as with their environment, bringing in their values, knowledge and past experiences in the way they engage with one another, with and through technology. Inclusion is a very complex and contextual issue that cannot be modeled as a single problem to solve, to which human-centered approaches and experience design are best placed to respond.

5.2 Supporting Participation in Research

There is no doubt that for robotic technologies to be inclusive and to support inclusion, the participation of people with intellectual disability in the research about designing or evaluating these technologies is essential. In this section, we will provide some insights on how participants with intellectual disabilities can be supported in a variety of research approaches, from control studies to co-design.

5.2.1 Control Studies and Task-based Research. Control studies, which tend to employ task-based approaches, can be cognitively demanding for participants. Evaluating technologies such as robots typically involves asking participants to perform a specific task and take part in interviews. When standard evaluation approaches to technology are not adapted to the needs and interests of participants with intellectual disability, the resulting findings are often framed in terms of barriers: what is too difficult for people to do, how the technology fails to respond to their cues. Standard approaches may also mean that participants are not interested in undertaking the task requested in the first place, or have not yet had the opportunity to develop competencies necessary to succeed. This can result in a misinterpretation of actual or potential role of technology. For example, if a researcher would like to study how social robots may assist people in their kitchen, it would be important to understand that people may have had limited opportunity to take part in cooking activities previously. If the robot is designed to provide a simulation on a simple recipe, a participant may not engage with the experience not because they don't see potential in the technology, but simply don't enjoy the proposed recipe. This example points to the key pillars of inclusive control studies: enabling participants to be supported while they engage with the robot, setting up tasks for success, and giving agency to participants to engage with their interests.

Enabling support for participation in research not only ensures that everyone can inform technology evaluation and development, it also provides cues about how the technology could be more inclusive, in addition to "testing" its effectiveness. Support, whether human or technological, can ensure that robots are the object of the evaluation, not the person. When a person can engage with a robot with the support of someone whom they know and who supports their daily activities, they can provide very rich perspectives on how the technology can enhance both agency for the person and experience for the support person. It recognises that people with intellectual disability may seek engagement with their support person through technology and empower them to demonstrate competencies in a supported context. Support can also be enabled through a method with technology, by letting people use a communication device for example, which could in turn reveal new limitations of the robot such as ability to understand synthetic voices or impatient robot behaviours. A communication device could create visual interferences for a robot that uses vision, and could also add the same distractive elements that people experience in their daily lives.

An approach that seeks to evaluate a robot rather than people would make sure to set research activities and tasks for success. It is also key to supporting dignity in research participation. If participants are asked to perform specific tasks, the research team should make sure that either a) the task is something for which the participant has already demonstrated competency, or b) the participant is provided ample opportunity to learn to perform the task before taking part in the research, or c) active support is provided for the participant to complete the task. Success is also directly linked to the difficulty of tasks. Randomizing tasks order for difficulty is often not supportive of participants who require scaffolding, and it makes sense to in the case of several task to build their competencies through increasing difficulty within the research. Finally, when a task cannot be completed, it is critical for the research team present (as well as when writing about findings) to highlight that this is not a failure of the participant, but a failure of the robot.

Use Case: Task-based approach

For some of the applications, we chose a Wizard of Oz (WoZ) approach, tele-operating aspects of the robot behaviour, visuals and speech. This enables participants to chose how they interact with the application and ensures that it always responds appropriately to their needs. The approach was supported by an application that enabled rapid responses by the experimenter with regards to the application itself, as well as incorporated a conversational interface. It was used for general conversation and greetings, where to put dissassembled components, encouragement to persist, and celebrating completed dissasemblies.

While WoZ methods don't usually disclose that there was a human operating the robot, until after the interaction event, for ethical and practical reasons, we took a transparent approach to WoZ, where participants were informed that a WoZ approach was being used, with the researcher located on the research site, and participants could see the researcher operating the robot from nearby. We have previously found that this does not have a significant impact on the interaction with the robot, and can help with ideation and understanding of how we can design and develop robot capabilities.

5.2.2 Beyond Verbal Contributions. Traditional co-design activities often rely on verbal abilities of participants, and require them to engage with abstract concepts for ideation and reflective practices based on what they remember from previous experiences. Co-design approaches for inclusive social robots tend to rely solely on the voices of proxies (for example support workers, family members or health professionals) who can articulate a reflection on existing barriers and ideate on possible use and designs of technology. We propose that co-design approaches that make use of working prototypes trialed by participants in contexts as close as possible to what they would normally experience, including being supported to engage with the prototype, can ensure that the perspectives of participants with intellectual disability can be accounted for.

When people are trialing working robot prototypes, or working prototypes of robot applications, they can best demonstrate to research team which features keep them engaged, which aspects require more support, and how they would integrate the robot in their day-to-day activities. All these, including aspects that require support, can be reflected upon for new versions of the prototypes, in continuous iterative cycles. Reflections and analysis of the observations during contextual interviews can also enable new concepts or new frames for the design to emerge and start new research or design projects. For example, our emerging understanding of Cozmo as a facilitator of connections between participants [4] has led us to continue exploring social robots, such as Pepper, with groups of participants rather than individuals in subsequent studies. It has also led us to set the potential for inclusion in future projects as one of the key contributions that social robots could make as collaborative technologies in inclusive workplaces.

The need to offer participant support in co-design is evident, and this support can come from the research team or from participants' existing supports. The research team can demonstrate, provide encouragements, and guide participants as required [9]. The co-design activities can make sure that participants can express themselves in non-verbal ways, making use of visuals in creative activities such as:

- collages: craft-type activities where participants can chose from a number of robot parts and styles with various background that can relate to context of use; if possible participants should also have access to pictures of themselves to include in collages and express how they see themselves interacting with the robots,
- image search: while driven by the designers, a large amount of images retrieved from the web can support participants by enabling them to use pointing to express their ideas,
- generative AI: similarly, generative AI can enable the composition of new images in large numbers in a manner that can provide visual choice for nonverbal participants to enrich their vocabulary for expressing design ideas, while also giving verbal participants opportunities to reflect on what the images are proposing (for example, if variation on a design are proposed).

Use Case: Beyond Verbal Expression with Choices

Offering a range of applications that participants could engage with meant that we could take onboard the choices people made as an input into what aspects of interaction they were more interested in. The prototype was also setup to enable and encourage participants to engage in any modality they like, with the WoZ approach enabling gestural modalities (they simply could show their component to the robot to know how to sort it) as a replacement, or complement to verbal interaction.

5.2.3 Co-design Activities. First, we would like to emphasise the importance of reciprocity in co-designing with participants with intellectual disability. Our Techshops approach has been derived from long term engagement with research participants and members of the organisation that support them [7]. Reciprocal elements of the Techshop approach include enjoyment and learning. Enjoyment is key to people wanting to continue to take part in research, and is derived from organising activities that engage participants on their interests, but also from approaches that are flexible and responsive to what resonates for participants. Enjoyment can be sustained by ensuring that participants can align their contributions with their interests or their daily living experiences by offering them choices of topics for investigation, choices of graphical designs (for example, many of our participants are fond of movie characters). Offering an informal learning experience is the base of the value proposition of the Techshops for participants. As a Techshop, a large proportion of the ”co-design workshop” is about demonstrating technology to participants and letting them have a go, without necessarily seeking their feedback or perspectives beyond observing how they engage with the technology. We have also observed that as participants learn about or experience technologies they have not had the opportunity to use before, they start to make more realistic suggestions during co-design activities, and their feedback is more informed. For example, we heard a participant suggesting at the beginning of a series of three workshops with robots that “robots should do a dance for me” making a new suggestion in the third workshop that “robots could assist when I withdraw money from the ATM”).

Members of support networks are invaluable in making sure that participants are comfortable, that the research team can understand their intentions, but also to offer some context around how the technology could be used as part of how they support people. The design teams has to remain attentive to possible bias introduced and make sure that the support is only provided as needed [20]. Actively seeking the perspective of members of people’s support network both as proxies and as enablers of the technology can help uncover the important values that might underpin adoption in the future [3]. As such, members of the support network who support the co-design activities are also research participants.

The robots presented to participants as working prototypes should be as accessible and flexible as possible. Accessible prototypes means that participants can take ownership of how they interact with the prototypes, and allows the research team to not-rediscover accessibility guidelines, if they can be implemented already. For example. guidelines for Web accessibility apply to many aspects of human-robot interaction. Easy-read language is also often easy-listen (even though there are very few studies on listenability). Flexible prototypes can be key to enabling as many ideas of participants to be embedded at short notice into the prototype, for example by modifying colours of lights or topics presented by a robot. This aligns with the principles of self-expression by design, and can enable the research team to take a ”reflection in action” approach [36], implementing additional features within a prototype within a session, in order to further prompt participants on an emerging idea that they identify.

Wizard of Oz (WoZ) approaches or simulations can also ensure flexible prototypes and help the design team to be responsive to how participants want to engage with the robot. The flexibility and efficiency offered via WoZ enables the trial of more complex interactions, adjusting nuance, and exploring personalisation for different users. The development and implementation of autonomous robot behaviours requires significant design and technical effort (Dautenhahn, 2014). The Wizard-of-Oz technique is a prototyping method that can be used to test and evaluate robot behaviours, by utilising a human operator behind the scenes to control aspects of a robot's behaviour, and is helpful for simulation of capabilities that have not yet been developed, like unscripted conversational dialogue (Dautenhahn, 2007). We have found in our previous work [23] that participants with intellectual disability address conversational systems, or robots, directly and genuinely even when researchers are controlling the outputs in a transparent manner (e.g. from a laptop on a table near the prototype). Additionally, we have found that the delay in responses inherent to Wizard-of-Oz approach was not critical to their engagement with the prototypes: participants did not express or exhibit any sign of impatience.

Use Case: Accessible Prototypes

The robot used in the study enabled both audio, gestural and visual modalities to be leveraged in the interaction. The simple language used on the application, combined with priority given to visual representations, provided an application that all participants could engage with.

5.3 Ethics

Our research has operated under a series of ethical clearance protocols that have been specified through several iterations with reviewers from the QUT ethics committee. In this section, we share some of the key elements of this protocol so that new researchers in the field can access established procedures for organising research studies, as well as arguments in support of participants' dignity and participatory approaches.

5.3.1 Partner organisations. Partner organisations are organisations (eg. Schools, disability services, etc.) who are keen to engage with the Program, and offer support to select and recruit participants. They can review each research activity to determine which participants are most likely to benefit from the research and/or are able to take part in the research given its methodology (eg. If the trialled technology requires reading, it would be inappropriate to invite participants who cannot read). Partner organisations can also help shape, and sometimes initiate the aims of the research Projects under the Program. They can provide an expert review of our research protocol materials (eg. Surveys).

Finally, Partner organisations can provide their own training to researchers and students to conduct the research, and may add their protocols (eg. Volunteer recruitment forms, requirement for first aid training) to those of the Program and the Projects.

Use Case: Partner Organisation

A partnership with the not-for-profit organisation started well ahead of the study beginning, with regular visits by the researchers for an ethnographic immersion to understand the participants, tasks and work environment. During these visits, the researchers also volunteered some of the work alongside future research participants. They introduced the robots to workers ahead of the study, with some demonstration of how the robot can dance, tell jokes or provide training. This early exploration allowed the researchers to establish the opportunity space for the robots. It was established at that point that the study would best run in weekly visits where the researcher would stay with the robot for the whole day, thus avoiding long disruption in daily activities.

5.3.2 Consent Procedures. Many adults with intellectual disability are lawfully able to make independent decisions, and provide informed consent (that is, they don't have a legal guardian). However, traditional research information sheets may not be appropriate to their reading and understanding abilities. As a result, the Program includes easy-toread research information and consent forms for participants to read or be read to. Verbal information and consent should then be renewed at the beginning of every session. Participants should also be reminded throughout sessions that they are free to leave the research at any time. Participants are also free to withdraw from the study, or from any of the research activities, at any time during the study.

Adults who can provide informed consent will be approached and invited to take part in the research through organisations or people who support them or communities they are part of (e.g. School, social activities, local communities), or they may be included in the Registry. Determination of ability to provide informed consent will be first provided by participants themselves, and for participants who are supported, will be confirmed by a member of their support network.

Adults who are not lawfully allowed to decide to take part in the research will be approached through people in their support networks, including individual carers or disability service organisations. Their guardians will be provided with the appropriate and adapted research information and consent form to sign on their behalf. They will also be explained the aims and implications of their participants in the research, in ways and terms that are appropriate to their understanding abilities and preferences. They will be attentively observed either by members of the research team who know them or by members of their support networks for signs of desire to pause or withdraw from the research.

Observations, video recording in context are ethnographic methods that can provide a deep understanding of inclusion through the lens of interpersonal relations. However, this means that all people who may be interacting with a participant, or either visible or audible on recordings, must also agree to the research taking place. Where appropriate this can be done through opt-out mechanism with signage available to inform people that research is taking place, however appropriate mechanisms must be in place for this type of implied consent when other attendees have a cognitive disability.

Use Case: Consent from Participants

Participants in the study included workers with intellectual disability, site managers, job coaches, as well as volunteers with intellectual disability. Volunteers with intellectual disability were generally attending with an assigned support worker, and were provided with easy-read consent form and information also passed on to their families or guardians for consent. Workers with intellectual disability were offered a choice of easy-read or standard consent form to take part in the study, and the site manager advised that no further consent was required by their guardians. Many of them live independently and can make decisions for themselves. All participants consented to being filmed while the robot was present on the work site, and consent to take part in interviews was renewed verbally when additional recording occured.

5.3.3 Participant Information and Demographics. Background and demographic information should only be collected to give context to the research and its findings (e.g., the analysis may show that the robots activities are particularly effective/ineffective for particular age groups or children/adults with particular competencies).

Where possible and appropriate, researchers should endeavour to collect participant information from the participants themselves. Self-report can focus on participants' abilities through mundane questions around activities of daily living as a proxy to understand cognitive abilities [32].

Furthermore, educators, support workers and parents/caregivers can provide information about children and adults who may have language delays. The parents/caregivers can supply the information about participants' capabilities, age and home environment. Educators may provide information about participants' participation and capabilities in the school or community environment.

Use Case: Participant information and demographics

Participants were verbally asked about their age, gender identification, work duties and work experience. In addition, through observations over the duration of the study, the researchers took notes about how they engage verbally with one another and with the technology, as well as physical competencies and skills that could inhibit interaction with the robot.

5.3.4 Interpretation of Non-verbal Self-expression. Non-verbal participants, participants who need support to self-express with words or participants who self-express in non-typical ways should be included in the research. However, the research protocols will need to ensure that they can express voluntary participation in the research, or at the very least their desire to pause or withdraw from the research.

In some long-term Projects, the researchers may be able to develop a deep understanding of the participant and understand and interpret their self-expression. In other instances, the protocol will need to include a person from the support network of the participant who can appropriately interpret their self-expression. For example, a participant who typically puts their hands on their ears or walks and open the door as a sign of excitement should be understood to not wish to stop or leave the Project.

Use Case: Interpretation of non-verbal expression

One of the participant was non-verbal and uses a communication application. He setup specific symbols in the application for the researcher and for Pepper, with the help of his support worker, so he could engage with the study. Other participants were using verbal language. However, filming occurred in the broader space in which the robot was operating, such that behaviours could be used as non-verbal responses to the robot's behaviour at these specific times. These behaviours included as paying attention to the robot, approaching the robot, or interacting with others while looking at the robot.

5.3.5 Risks. Participants may feel upset if they do not know how to let the research team know that they would like to stop participating or withdraw. In addition to asking regularly if target participants are happy to continue, the research team can be guided by the supervisors and/or support workers to learn signs of such discomfort that they may display. Support workers and/or supervisors who are familiar with the target participants can be present to also support target participants to express themselves, should they need such support.

The use of interactive technologies can present short term and long-term risks to participants, whether or not they have a disability. However, in our ethical clearance protocols, we argue that technologies are pervasive in society and as a result, and people with disability should be fully included in their design and use. We believe that the benefits of evaluating and supporting engagement for participants with intellectual disability and/or autism outweighs the risks they may present. However, as some of these risks may be heightened for some participants through specific sensitivities or co-morbidities, researchers should establish mitigating strategies and where appropriate, include a summary of the risks and/or link to manufacturer's disclaimers in consent forms.

When participants are not already engaging with the technology studied in a project, risks can be mitigated by

- Providing information to participants about heightened risks
- Verbally engaging with the participant, or a member of their support network to ensure they understand the risks, and to ensure this is not heightened for them (eg. participants sensitive to light or sounds, or specific triggers).
- Make use of safety equipment where available (e.g. iPad cases, safe mode in online environments)
- Supporting and monitoring use

Technology providing access to visuals present a risk to trigger emotional reactions in some participants. When present, these triggers are typically specific to individuals. In order to mitigate this risk, researchers can engage with participants and their support workers verbally to establish what these triggers may be. Similarly, technology providing access to online information presents a risk of providing access to inappropriate content. In order to mitigate this risk, researchers can make use of "safe modes" in web search and social media environments. Long-term use of technology, particularly technology employing screen, can lead to addiction. This risk will be mitigated by researchers by ensuring the involvement of support networks in long-term trials.

Large technological equipment, such as social robots taller than 1.50m, present a physical risk to participants if they fall on them. These risks will be mitigated by the establishment of safe protocols for their use, and included in the participant information sheets. Furthermore, video cameras embedded on a social robot present a risk of misjudging privacy and unintentionally exposing private content. This risk can be mitigated by providing targeted education to participants on these risks in a form of a workshop or individual training, as well as encouraging or imposing use in the presence of people from support networks.

Due to the social and interactive nature of these robots, some participants may perceive the robot like a friend and develop an attachment. The research team can ensure that behaviours that reveal excessive attachment can be monitored, and that participants who are developing such attachment can be reminded of the technological nature of the robot.

Use Case: Risks

The robots being used in this research were be commercially available social robots (Pepper and Alpha Mini) under 1.5m tall that have previously been trialled with this demographic of participants (e.g. Pepper, (Mitchell et al., 2021), small robots trialled in Project 2). All participants' input to the robots were processed by the operator of the WoZ setup, thus completely eliminating risk of 3rd party access. The application presents a limited amount of visuals, with imagery similar to workplace elements, thus eliminating risks of triggering imagery

6 Conclusion

This paper has provided an integrated overview of co-design technology research we have conducted with adults with intellectual disability in the last decade. We have focused on our experiences with co-designing with social robots, but incorporated lessons we learnt from a range of methods and frames we have developed over time in partnership with our research participants in a broader program of research.

We hope that the approaches, frames and perspectives we have presented in this paper will inspire readers to investigate inclusive approaches to research they already undertake, or to start new projects for inclusive robotics. The approaches presented here also address some of the recently raised concerns that inclusive robotics research with autistic people is overwhelmingly following a narrative that is not what people really care about. That is, most of the research focuses on a "rehabilitation" goal to support people in fitting social norms [22]. Our research suggests some new ways of positioning the role of robots in supporting inclusion. This positioning can be embedded in existing and new co-design methodologies, leveraging materials used for supporting creativity while orienting the reflection towards the self-actualisation of participants.

While this paper has integrated best practices to date, they reflect a limited amount of explorations and research that has been conducted, generally focusing on specific stages of design. There are opportunities to adapt more comprehensive approaches for the co-design of robots to align them with the recommendations presented here. For example, future work could explore how robot co-design canvases [2] can structure the recommendations in this paper for an approach that could be both inclusive and comprehensive.

Our focus has mainly been on social robots, however, we believe that the approaches and positioning will equally apply to collaborative robots. For example, cobots in workplaces should support people's work as much as they should connect them to co-workers, and the role of work coaches would be as critical as that of the support workers in the studies we have discussed. We also believe that the new frames and approaches we have presented can be leveraged for inclusive research with marginalised cohorts other than adults with intellectual disability. Respectful co-design that supports self-expression throughout the process is likely to empower marginalised users who are not used or comfortable sharing their perspectives, and visuals can be a powerful tool to support both self-expression and reflection for most co-designers.

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