Attributes of robots co-designed with people with intellectual disabilities to support them in diverse contexts

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Robots have the potential to support people with intellectual disabilities. However, their requirements and preferences are not taken into account when designing robots. In this study the research team co-designed robots with adults with intellectual disabilities and their support workers through collaborative workshops that took place over three phases. This collaborative approach recognizes the expertise that people with intellectual disabilities have in understanding the challenges they face and the types of support that would be most helpful. By actively involving individuals with intellectual disabilities in the design process, we can ensure that the resulting robots are tailored to their specific needs. abilities and interests. In the first phase we provided our participants with collage materials to design a robot for a chosen context. In the next phase we showed our participants what their robot would look like in the context they chose using generative AI. Participants informed us about their robot's role, communication modalities, physical attributes and capabilities. In the final phase people were able to create short interactions with their robots that were simulated by a small humanoid robot using block-based programming. Our findings revealed the contexts in which our participants wanted a robot to support them. People preferred robots that have a humanoid appearance and were smaller than them. Multimodal communication methods like speech, lights, sound, gestures and music were favoured as they cater to diverse abilities. The role the robots can play in the lives of people is also discussed in this paper.

CCS CONCEPTS • **Human-centered computing → Accessibility; Empirical studies in accessibility;**

Additional Keywords and Phrases: Intellectual Disability, Cognitive disability, Human-robot Interaction, Social Robots, Co-design, Accessibility

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1 INTRODUCTION

Robots have the potential to support people with intellectual disability and the people in their support network [25]. Although robots have been designed to support marginalised communities like people with mild cognitive impairment and dementia [22], robots have not been designed with people with intellectual disability and people in their support network. And this is an issue when it comes to integration of robots in the daily lives of people. Domestication of technology is about how the devices are integrated into and used in everyday lives of the users. Design and domestication of technology often go hand in hand as domestication is anticipated in design and design is completed in domestication [34]. However, when technologies are not designed with specific groups of people in mind, domestication can be hindered.

There is also limited research about how robots can support people with intellectual disabilities in diverse contexts. Previous research has focused on supporting people with intellectual disability at work [20, 21, 41] and supporting learning [25, 33, 41]. However, these studies used pre-existing robots that were not specifically designed for people with intellectual disability. The aim of this exploratory research is to understand what people with intellectual disability want the physical attributes of robots to be like, where they want support, what tasks they want support with and how they will interact with the robots. To achieve these research aims the research team conducted collaborative workshops called Techshops [8] with 10 participants with intellectual disability and 3 support workers. The Techshops were run over three sessions and had three phases. The first phase was around building familiarity around robots with a discussion about what people already knew about robots, a presentation on robots and free play with robots. Next participants were invited to design robots in a specific context using collage materials provided to them. In the second phase we combined their creations with the context they chose on the generative AI platform Midjourney so that they can visualise their robot in the context it was made for and provide feedback. Phase two also included an exercise to help people visualise how big they wanted their robot to be and to end this phase we introduced our participants to block-based robot programming. In phase three we programmed interactions for robots in the context they were designed for. The findings from our Techshops include the contexts that our participants chose to design robots in, the robot's physical attributes, communication modalities, ideal robot size and the roles the robot can play in these contexts.

Our research on co-designing robots with people who have intellectual disabilities has important implications for advancing accessibility and inclusion in technology development. By actively involving this community as equal partners in the design process, we can ensure the resulting robotic systems are tailored to their specific needs, preferences and the contexts they require support in. This collaborative approach not only produces more universally accessible technologies, but also helps counter stigma and promote the full participation of people with intellectual disabilities in shaping the innovations that impact their lives.

2 RELATED WORK

The related work section will begin with look at previous research around robots and people with intellectual disability to understand what has been done and to identify the current gaps in literature. Next, we will look at research around co-designing with people with intellectual disability and the challenges when conducting co-design. And the final section looks at co-designing robot using tangible tools.

2.1 People with intellectual disability and robots

People with intellectual disability are a heterogeneous population with diverse abilities, skills and interests [13]. The formal medical definition of the American Association of Intellectual and Developmental Disabilities [1], is that "intellectual disability is a disability characterized by limitations in both intellectual functioning and in adaptive behaviour, which covers many everyday social and practical skills", and originates before the age of 22. Intellectual functioning is also known as intelligence which refers to the general mental capacity such as learning, reasoning and problem solving. Adaptive behaviours are a collection of conceptual, social and practical skills that are learned and performed by people in their everyday lives.

Robots can have different roles such as teacher, instructor, companion and play partner [31]. Pepper has been used as a learning partner that can complement support workers when teaching new skills and can enhance social engagement [25]. Tablets on the robot can increase the ability for it to provide a consistent and repeatable delivery of content [25], be it for learning or entertainment. A humanoid Nao robot was able to improve verbal communication among three students with autism or intellectual disability in a public secondary school in South Australia. The participants were eager to work with Nao and intrinsic interest in the robot helped bring about improvements in their communication [32]

People tend to anthropomorphise robots and their behaviours and this can lead to social robots like Anki's Cozmo helping to increase social interactions among adults with intellectual disability [7]. The ability to play games collaboratively helped people to interact with their peers in a playful manner. Robots can be used as an intervention to increase engagement in positive mental health practices [31]. Experts who work with people with intellectual disability stated that robots can perform activities such as encouraging people to exercise and providing knowledge to people about personal hygiene and taking care of themselves [31].

Robots can reduce the work load of caregivers who work with people with intellectual disability and help them focus their time and efforts in providing personalised attention. [31]. Support workers stated that robots can help engage people with activities that they do in disability day centres [7].

Humanoid robots like Nao and Pepper tend to be expensive and unaffordable for many people and disability service providers. However, robots like the Lego Mindstorm which is a cheaper non-humanoid robot with less features than a Nao robot, can have more engagement from students with intellectual disability and is just as effective in helping them achieve their learning goals [4]. The previous literature has only looked at commercially available robots that have not been designed with the needs of people with intellectual disability in mind. It is essential to co-design robots with people with intellectual disability so that their requirements can be identified and robots that complement their abilities can be designed to support them.

2.2 Co-design and people with intellectual disability

One of the challenges when co-designing with people with intellectual disabilities is the ideation phase which requires abstract and speculative thinking [40]. Co-design workshops are a common tool when ideating among stakeholders. Engaging in traditional co-design activities like workshops can be challenging for people with intellectual disabilities as these activities can rely on higher order cognitive skills [11] and researchers must take care to develop methods that cater to the requirements and competencies of their participants. It is the researchers responsibility to lower the barriers for people to express themselves by providing a stimulating and playful environment that supports the creativity of the participants [40]. Co-design workshops can be structured in ways that assist with participation of diverse groups of people by providing materials and options for engagement that help articulate their ideas [30].

Self-expression is an important facet of co-design which helps people to present their values, background and interests to others [3]. The dominant forms of self-expression coming in the form of verbal and written communication which are not accessible to everyone. Different modalities of self-expression need to be provided to help people with diverse abilities take part in the co-design process [3]. Being influenced by other people in the group is also a common issue for people with intellectual disability [40]. However, having the capability to communicate their thoughts within a group can give individuals a sense of confidence. The act of self-expression can result in the group discovering unique attributes of each member and associating those qualities with individuals. This establishes a sense of identity and belonging for the person who is expressing their thoughts [3].

People with intellectual disability maybe uncomfortable sharing their views with people they are unfamiliar with or in unknown contexts [37]. Guidance from support workers can help researchers engage people with intellectual disability in co-design [36]. Support workers play different roles in the design, use and adoption of technology. They are both proxies for the people they support and co-users of the technology [6]. Involving support workers in these dual roles in the co-design process can help to include the values and requirements of both people with intellectual disability and the support workers.

2.3 Co-designing robots

Using tangible tools for co-designing robots can be useful when trying to imagine future applications for supporting diverse groups of people. A study by Moharana et al used tangible tools such as basic shapes and abstract objects to help caregivers of people with dementia to visualise the appearance of a robot to support them and modality and interaction cards to design what the robot can do [26]. Collaborative tools like canvases can be useful when co-designing robots as they provide structure and clarity, encourage groups of people to work towards a shared goal from different perspectives and can encourage the sharing of ideas [5]. Co-design with multidisciplinary professionals has been used to develop interventions to support children with Autism through a social robot named KASPAR [19]. Using tangible toolkits for designing robots with people with intellectual disability can help alleviate barriers to ideation.

Our study aims to address the gap in research on co-designing robots with people with intellectual disabilities. By involving adults with intellectual disabilities and their support workers in collaborative workshops, we seek to understand their preferences for robot attributes, communication modalities, and roles in various contexts. Our goal is to explore how robots can be tailored to support the specific needs and interests of people with intellectual disabilities, while also contributing insights that can inform the development of more accessible and human-centred robotic technologies for this population.

3 METHODOLOGY

"Techshops" are a collaborative workshop-based approach to engaging people with intellectual disabilities with technologies. Techshops combine learning, exploration and play to provide a fun way to introduce participants to emerging technologies while also helping researchers identify new use cases and areas for future work [8]. The research team conducted Techshops where we co-designed what their ideal robot would look like and do. The research took place over 3 weeks in 3 phases. The first techshop was two hours long and the subsequent two were one hour each

3.1 Participants

The research team has partnered with a disability service organisation (DSO) who invited some of their clients at two different day centres to attend Techshops weekly at (anonymised). The participants were identified as having intellectual disability by the DSO. Further medical diagnoses were not collected as they are not relevant to this study. The people who attend the day services of the DSO require a support ratio of one support worker to four people. Ethical clearance for this study was provided by (anonymised University name). We worked with 10 people with intellectual disability (P1-P10) and 3 support workers (S1-S3). Table 1 includes the language capabilities of participants as it was an important way to identify how people provided their ideas and feedback. Non-verbal people communicated through gestures (body language, pointing) or with the help of their support workers. Support workers were part of the co-design process in the role of a proxy for the people who they support [6]. Support workers understand the people who they support better than the research team and can help to interpret their needs.

Table 1: Participants with intellectual disability details

Participant ID	Gender	Age	Language capabilities
P1	M	Late 40s	Short phrases
P2	F	50	Short sentences
P3	F	37	Short phrases
P4	M	48	Minimally verbal
P5	M	60	Short sentences
P6	M	63	Articulate structured sentences
P7	M	30	Limited speech. Uses a Proloquo2go (assistive technology) with support.
P8	F	31	Articulate Speech
P9	M	38	Short phrases
P10	M	53	Non-verbal, limited sign language.

3.2 Phase 1

The first Techshop began with a tour of the university's robotics research centre. A member of the robotics centre guided participants through the space and presented the robots that were at the centre. Some of these robots are humanoid like Softbank's Pepper robot and others are non-humanoid, such as drones and arm robots. After the tour, the session began with the research team having a discussion with our participants around what they currently know about robots. People mentioned some of the robots from pop culture that they liked. Their answers ranged from Optimus Prime, to WALLE-E to The Terminator. We then asked people what they wanted from robots. Answers varied from robots that can help them complete a task to robots that can be a companion. We then conducted a presentation on robots, what they are and what they can be useful for.

Next, we introduced people to the robots that we brought to the Techshops, Pepper, Dash, Alpha Mini and Miko 3 seen in Figure 1. The robot hardware devices are all available commercially off the shelf, and are commonly used in educational settings. Softbank Robotics' Pepper [39] is a programmable humanoid robot that is 1.2 metres tall with the ability to move its arms and head. It has a tablet on it that can be used to display content. Wonder Workshop's Dash [44] is a vehicular robot that can respond to voice, navigate objects, dance and sing. UBTECH's Alpha Mini [45] is a small humanoid robot that can engage in multimodal interactions through voice, facial expressions, body gestures, tones etc. It also can perform humanlike movements including, walking, dancing and push ups. Alpha Mini and Dash have graphical block-based coding for customisable interactions. Miko 3 [46] is a robot designed for children with an interactive and emotive screen for a face. It has wheels for movement and has content for learning and entertainment. We set each table up with a different robot and participants were encouraged to move to different tables to interact and engage with various robots.

For the final activity, we invited participants to imagine a robot for a particular context. We provided printed images of several locations such as the bedroom, kitchen, movie theatre, garden, grocery store, bathroom, library and the bank. The research team was familiar with many of the participants and the activities they do at the centre through previous research. They were thus able to identify these potentially relevant contexts, carefully selected based on what people commonly do or places they often spend time in. We provided participants with collage materials like cutout pictures of robot parts such as heads, arms, legs, wheels, tread tracks, along with coloured pens, paper and sticky tape. We also asked our participants to consider what the robot would do in the context that it is being designed for. The session concluded with people crafting their robots and then describing its features, capabilities and uses to the whole group. Support workers helped participants share, thus supporting a balanced representation of perspectives from both verbal and non-verbal participants.

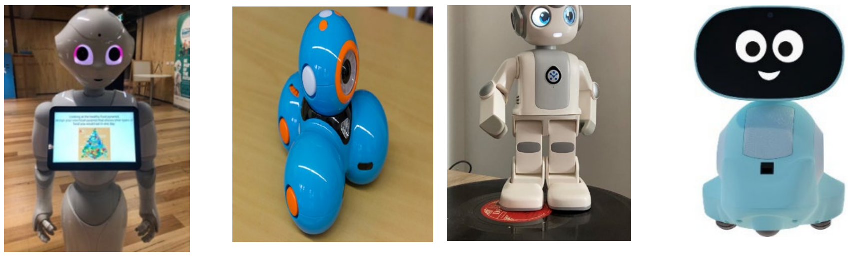

Figure 1: Left to right Pepper, Dash, Alpha Mini, Miko 3

3.3 Phase 2

In preparation for the second Techshop, the research team used Midjourney [47], a generative artificial intelligence program, to combine participants' creations with their chosen contexts. Midjourney users can create artwork by using Discord bot commands. We used the '/blend' command to combine two images together: the robot the participant created and the photo of the context that they chose. The '/blend' command does not require any further prompts. This was done to give people an idea of the robots working in the space that they were designed for. We began the workshop by showing the images created by Midjourney to the group. We encouraged everyone to share their thoughts and provide feedback on all the robots shown in context.

Next, we wanted to understand what size people wanted their robots to be. For this we used the video call software Zoom, where their robot was used as the background to see how big they wanted the robot to be when compared to them. People could see themselves and the robot on the screen and move towards the screen if they wanted to be bigger than the robot and away if they wanted to be smaller than the robot as can be seen in Figure 2.

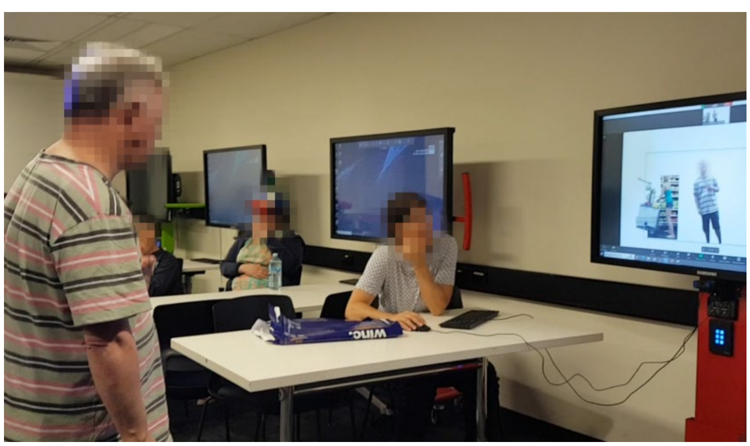

Figure 2: Using Zoom to identify the preferred size of the robots

The research team then conducted semi-structured interviews. The support workers assisted by helping us convey our questions and explaining the answers of non-verbal participants. The questions were about what their robot does, how it communicates and its role (companion or tool?).

We concluded phase 2 by introducing people to block based programming of two robots, Alpha Mini and Dash. People were shown how to do block-based programming with examples and we encouraged them and their support workers to chain some actions together.

3.4 Phase 3

In the third and final Techshop, we asked our participants to imagine and share what they would want the robot that they designed to do in specific situations, so we could program an approximation of that onto Alpha Mini. Due to time restraints we were only able to do this activity with three participants, P1, P2 and P9, but everyone was able to observe and contribute ideas. The researchers asked the participant to describe a short scenario or interaction where the robot was in action. The activities of the robot were broken down into short steps. We used coloured post it notes for different actions, orange for movement, yellow for verbalisation and pink for expressions. One researcher then used Alpha Mini's block-based programming interface and tried to emulate what the participant wanted. The aim was not to teach programming but to help the participants understand that humans can control the behaviours of the robot. As a result, it was the research team that did the programming based on the sequence of actions provided by the participants in the final Techshop.

3.5 Data analysis

All the Techshop activities were video recorded. The researchers engaged in debrief sessions after each Techshop and these were audio recorded. For this paper, the research team selected all the data that was related to the outcomes of the Techshop activities and conducted thematic analysis on that data [10]. A full analysis of the methodology is beyond the scope of this paper. The themes were first established individually by the authors, then iteratively refined through discussion between the authors and organised in a collaborative approach. All the research data was reviewed, including the artefacts created by our participants. The thematic analysis produced four overarching themes: preferred contexts, robot attributes, communication modalities and the role of the robot.

4 FINDINGS

4.1 Overview of participants' robot designs

The following are descriptions of the robots provided to us during the end of the first session and during the semi-structured interviews in the second session. Figure 3 shows some of the robots designed by the participants.

P1 created a robot who can support people at the bank. The robot stays at the bank to help anyone that needs assistance withdrawing money. It resembles a small humanoid robot and uses light, sounds, music, speech and gesturing to communicate.

P2's designed a robot that can help her keep her bedroom clean and perform tasks like folding clothes. The robot's appearance in her collage is difficult to identify as she has placed body parts in random places on the paper. There are two heads, one looks mechanical and the other human and two arms, one machine like and one humanlike. After blending the images on Midjourney, the robot resembled a small robot with four appendages. She requested a face to be added to the robot as the Midjourney output lacked a face.

P3 created a robot that can be used for two contexts, the supermarket and movie theatre. At the supermarket the robot will assist her by grabbing items off the shelves and putting it in a basket. In the cinema it will assist her by getting her food and drinks from the counter. It has a humanoid appearance and does not talk. The robot moves fast using its wheels. The robot can communicate using lights and it can also recognise certain gestures like when people raise their hands and key words such as 'popcorn please'. However, P3 stated that the robot will tell people off if they ask for something else.

P4's robot was designed with the intention of helping him in the garden and with shovelling. S1 assisted him during the activity and helped explain what the robot does. The robot had a screen and used lights on its screen to indicate the status of the task it was currently doing. Red means task is not complete, yellow means it is half-finished and green means the task is complete. In addition to using lights, it also uses gestures to communicate. The robot moves fast using wheels and has humanoid arms for shovelling.

P5's robot was designed to help with cutting trees and trimming bushes. S1 helped explain what the robot can do. The screen can be used to map out the garden and select which trees and bushes to trim. It moves slowly and communicates using gestures, lights, music, speech, sounds and touch.

P6 designed a vehicular robot to support him to pick and carry groceries in the supermarket.

P7 wanted a large robot that can purchase and carry food for him at the movie theatre. The robot does not accompany him inside the viewing area and waits outside. P7 included many different parts in his design like tread tracks, robot arms, a body similar to Boston Dynamic's Spot robot, drone wings and a humanoid head.

P8 wanted a robot that can help her to withdraw money from the ATM machine. The robot has arms similar to Pepper and a humanoid face. It uses the arms to press buttons on the ATM and hands money over to the customers. It moves slowly using wheels. The robot can connect to a customer's headphones using Bluetooth and talks with a robotic voice. In addition to speech, it also uses lights to communicate the status of its task. During the interviews she stated that similar to P1's robot, the robot that she designed stays at the bank.

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. The robot has a screen, human arms and hybrid human/machine legs. It communicates by speech, touch, gesture and making sounds like one of the robots from Star Wars, R2D2. P9's robot can scan the fridge, identify the items in it and suggest recipes based on the available ingredients.

P10 worked in collaboration with S2 to create his robot. P10 is non-verbal therefore S2 explained the capabilities of his robot. The robot is a shopping assistant. The screen on the robot would have P10's shopping list with pictures of the items that he needs to purchase. It has long arms to reach all the hard-to-reach items on the shelves and it can put items in the basket which is built into the robot. The robot would walk alongside him while shopping. It has tread tracks, two robot arms, basket and screen.

4.2 Preferred contexts

The research team wanted to understand where people wanted to have a robot support them. The context options given to our participants were bedroom, kitchen, movie theatre, garden, grocery store, bathroom, library and the bank. Several printouts of these different locations were provided so that people could choose the ones that they wanted. Supermarket was the most popular option with three participants choosing it. Bank, garden and movie theatre had two and the kitchen and bedroom had one each. P3 chose two settings for her robot, supermarket and movie theatre. All the other participants chose one setting each.

4.3 Robot attributes

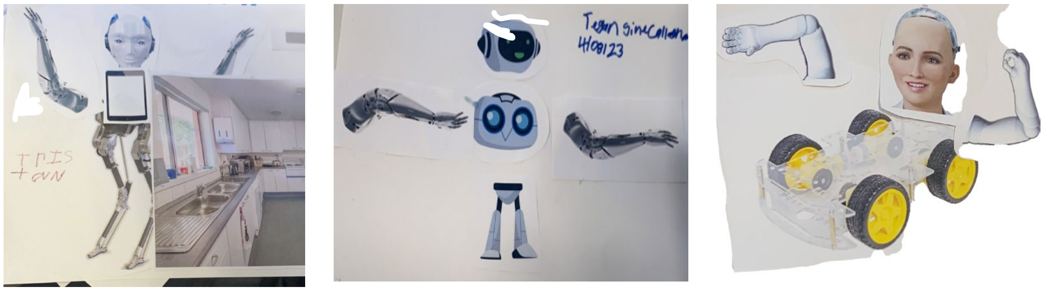

Figure 1: Left to right P9's robot, P3's robot and P8's robot

Every participant except one had a robot with a head. P10’s robot did not have a head and was built purely for the purpose of helping him with shopping. The heads of the other robots varied in their level of anthropomorphism. Three robots had a screen which had a digital face, three robots had humanoid faces that were more machine like, two robots had a humanlike face and P2’s robot had both a machinelike head and a humanlike head. There was an even split between people who preferred a fast robot and people who preferred a slow robot. Five robots had legs, three had wheels and two had tread tracks.

During the second session the research team showed the participants their robots blended into their chosen contexts using the generative AI platform Midjourney. This gave them the opportunity to see their robots in action and provide their feedback. People liked seeing the Midjourney outputs and many of them said they were happy with what they saw. P3 said that she liked that her robot was inside the theatre and wanted it to sit with her. People commented on the usefulness of P10’s robot arms for picking things that are out of reach. P2 said she would change the wheels and have four legs instead. She also said she would like a face that is capable of speech. Figure 4 depicts P9’s, P3’s and P8’s robots after being blended with the chosen context in Midjourney.

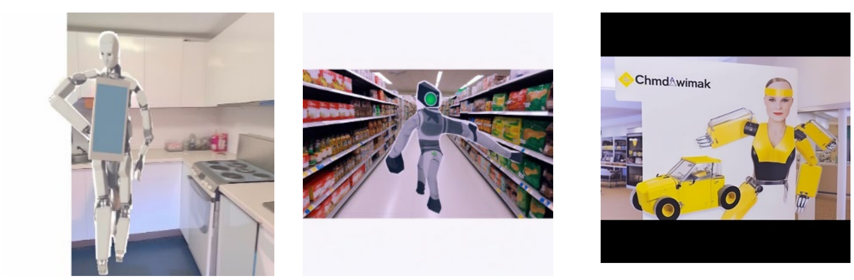

Figure 4: Left to right P9's robot, P3's robot and P8's robot blended in Midjourney

Most people preferred a robot that was smaller than them and around the size of Pepper. This could be because they did not want a robot that was too intimidating. P4 wanted the robot to be his size and P2 wanted her robot to be a lot smaller than her. Only P7 wanted a robot that was bigger than him. He said his robot was going to be much taller than his support worker S2.

4.4 Communication modalities

Many people preferred robots that have several modalities of communication. Figure 5 shows the preference of communication modalities. Speech and lights were the most common preference among participants. Speech could be used in novel ways like P8 who suggested that her robot can connect to people's headphones and speak to them so that other people cannot listen in on the conversation. Speech was used by many robots who also doubled as companions, and robots with humanoid heads were expected to be able to speak. Speech can also help with utility for example, P10's robot, where the owner of the robot can speak to it to give it instructions on which groceries it needs to pick out. The robot maybe programmed to pick out specific phrases like 'popcorn please' that P3 identified as important to them.

Lights can be used to communicate the progress of a task like with P4's robot where red means not complete, yellow half completed and green means completed. P1, P2 and P9 were the three participants who took part in the coding activity in phase 3 and all three of them requested lights. P2 and P9 wanted lights to indicate that a task has been completed and P1 requested a light to indicate that the robot understood what the person said.

Music and sound were also used for communication purposes. P9 said his robot would make sounds like R2D2 while it was in the process of working. P2 requested 'silly music' while her robot is cleaning her room. Hearing these sounds would let the person know that their robot is currently working on a task.

Gestures like pointing at things were a popular way for robots with arms to communicate things to people. For example, P4 stated that his robot would point to indicate the location it was moving to.

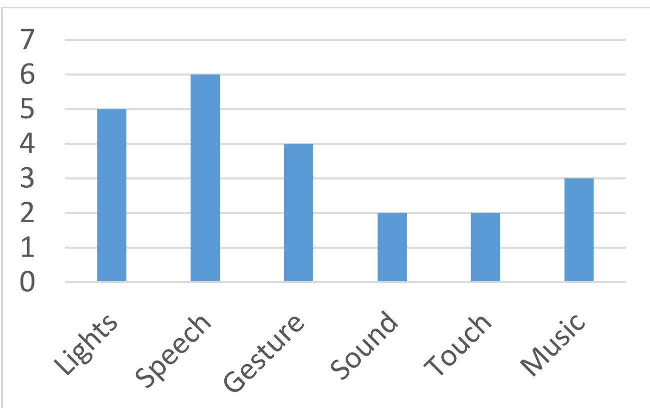

Figure 5: Preference of communication modalities

4.5 Role of the robot

Even though most people's robots were designed for helping them do a particular task like help with grocery shopping and cooking, they viewed the robot as a companion rather than just a tool. P9, P4 and P3 said their robot was a companion while P1, P2 and P5 said their robot could be a friend. P8 and P10 said that their robots were just tools, with P8's robot staying at the bank to help people withdraw money and P10's robot helping him do the grocery shopping. Interestingly some participants wanted the robot to help them with tasks but not do everything for them as to maintain some autonomy and independence. P9 said that his robot will help him with cooking by providing him with recipes, getting items for him for various shelves and assisting in the process of cooking but he will still be involved in certain tasks.

4.6 Programmed actions

Having a say in low level actions during co-design can help people visualise how their robot will interact with them. As indicated in section 3.4 three participants planned out a short sequence of actions for their robot. We used post it notes of three colours; orange for movement, yellow for verbal communication and pink for non-verbal expressions. The support workers helped elicit answers from participants by asking questions and prompting. Figure 6 shows the sequence of actions that P9 mapped out with the support of S2.

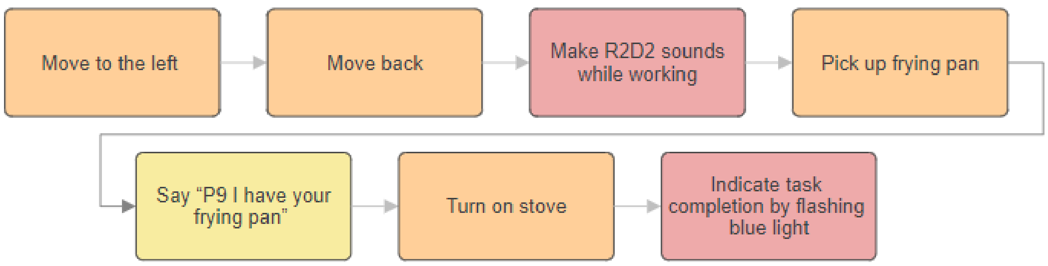

Figure 6: Sequence of actions

P9 initially said 'make pizza' but S2 prompted him to break the task down to small tasks like pick up a frying pan and put ingredients on the pizza. P9 was asked how he would like the robot to indicate it has completed a task. He said he wanted a blue light to signal completion but Alpha Mini could only do green. S2 asked what kind of sounds it would make while working and asked if it would sound like Star Wars robots like R2D2 and C3PO. P9 said he would like the robot to make sounds similar to the ones made by R2D2. Figure 7 shows the sequence that we wrote down on the notes and the block-based programming inputs to make an approximation by Alpha Mini. After Alpha Mini conducted the sequence of actions, the researcher handed the tablet over to P9. He looked at the code blocks and at the options available to him. He then replayed the sequence and agreed that it was similar to what he asked it to do. P1's sequence of actions was related to how the robot would help him in the bank and P2's was about how the robot would help her clean her room. Being able to create these low level actions with our participants showed us how they would want to work with their robots. We observed that participants wanted the robot to help them but they did not want the robot to do the whole task and would rather contribute to the task as well.

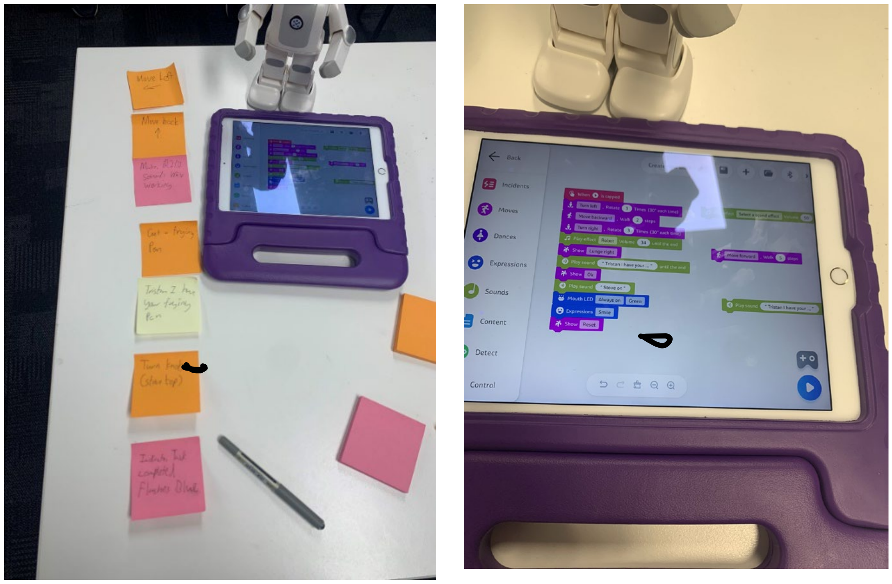

Figure 2: Actions provided by P9 and the block-based code entered to Alpha Mini

5 DISCUSSION

5.1 Physical features of the robot

Our participants preferences can help inform the design of robots for people with intellectual disability. The robots designed by our participants were skewed towards humanoid features with nine out of ten robots having faces. Previous research with people with intellectual disability has revealed that humanlike relatable behaviour of robots can result in positive interactions [7].

Nine participants also included arms for their robots with five being humanlike arms with hands that have fingers and three robots with machinelike gripper arms and one robot with both types of arms. Common tasks that their robots were designed were for picking up items, handing things to them and carrying items. This requires arms that can perform a wide range of motions. The type of arms chosen may have been influenced by the tasks that the participant had in mind for the robot. They could also have been influenced by the robots that they saw such as Pepper,Alpha Mini and the robot arms in the robotics research centre.

Many people preferred robots that were smaller than them. This ranged from slightly smaller than them to about the size of a cat. Having the ability to visualise themselves next to the robot helped our participants make a decision without having to do any abstract thinking. At times there were contradictions between the size of the robot and the task they had to do. P9's robot for example had to reach for items in high shelves in the kitchen but was shorter than him. The robot circumvents this by having extendable arms. This creative problem solving came about with the help of his support worker, S2.

5.2 Multimodal communication

All our participants chose multiple forms of communication with their robot. Artefacts designed for use by people with intellectual disability should ideally have multiple modalities of interactions to cater to different abilities and interests [43]. Communicative signals are not in solitary instances, but rather are embedded in interactions which could encompass various participants, intricate patterns of turn-taking, and complex forms of feedback [18]. The need for clear communication and turn taking was seen when our participants co-designed interactions in phase 3. They wanted the robot to inform them of its progress on its activities through signals like sounds and lights. Robot signals can be characterised by their origin, deliberateness, reference, genuineness and clarity [17]. The origin of robot signals can be classified as biological, artificial or a hybrid of the two. Deliberateness is important because unintended consequential signals from robots can cause confusion. For example, when Pepper was addressing one participant but looking at another, this caused confusion. Reference tells us whether the signal is denoting something in the environment of the robot or a non-referential which is about its internal state. Some robot communications are deceptive in that they give the illusion of feelings and emotions. Many of our participants enjoyed the illusion of feelings and emotions expressed by robots like Pepper and Alpha Mini during free play. Many of their designed robots had heads that could express emotions. However, designing emotions can have undesirable consequences and the designers of robots may end up designing robot behaviours that are misinterpreted by people that interact with them [28].

Speech was the most popular mode for communication among our participants. Lights, sounds and gestures were also popular choices and these modalities were particularly preferred by minimally verbal and non-verbal participants. People requested sounds, music and light to indicate the status of the robot's task and these types of communication are signals that are explicitly designed by the roboticists [16]. Robots have successfully used recognisable human sounds like 'errr' when trying to communicate delays to users [27]. The ability for people to test out different sounds, lights and other signals is necessary for them to figure out the types of signals that work for them. That is why the robots designed for people with intellectual disability need to be customisable. Cues like the sound of a robot's motor could be implicitly or explicitly interpreted by the receiver as a sign that it is working [16]. These cues were not present in our Techshops and could be investigated in future work.

5.3 Companion and tool

Our participants created robots that can support them in a variety of different settings. The robots were task focussed which could be stated as their primary purpose. Technology can be used to support independent living among people with intellectual disability [12, 14]. Previous screen-based assistive technology has lacked the ability to support people in physical activities. Robots on the other hand are able to assist with cognitive tasks and physical tasks. P9's robot for example can help him by turning on the stove, handing him ingredients while also prompting him by telling him what he needs to do next in the recipe.

Some of the participants designed their robots for tasks that can be done by other machines, such as the banking robots. ATM machines serve a similar purpose, however, the decision to draw a robot that acts as a middleman between them and the ATM shows that the ATM machine is not accessible to them. Exploring potential affordances, interaction modalities and features of robots can give us an understanding of how to make existing environments more accessible.

Despite the robots being task focussed, many participants also stated that they wanted their robot to be a companion or friend. Loneliness is a common condition among people with intellectual disability [2]. Having friends and social opportunities are among the most important things in their lives [24]. A robot can never replace a human companion or friend but they may be able to reduce loneliness and even facilitate interactions with other people [7].

5.4 Contexts of support

People with intellectual disability have diverse support needs and previous literature aligns with our participants choices for where they need support. Research indicates that people with intellectual disabilities frequently require support across various community settings and activities. In the context of shopping, many individuals need assistance with grocery shopping, often accompanying family members or requiring staff support, while limited disposable income can also impact their ability to shop independently [42]. Our participant's created their robots to help them pick out items, carry them and assist with cognitive tasks like helping them remember what to buy. At home, support is often necessary for instrumental activities of daily living, such as meal preparation and managing finances [42]. Participants in our study wanted robots at home to help them with cooking and cleaning while maintaining a level of autonomy for themselves so that they can still do the parts of the tasks that they enjoyed. Support is also required to access and navigate entertainment venues like movie theatres [29]. Banking services also frequently necessitate support for people with intellectual disabilities to manage their finances effectively [42]and robots stationed at banks were created by our participants for this purpose. It is important to note that the level of support required varies significantly based on factors such as living situation, disability, and personal history [29, 35, 42].

5.5 Co-design approaches

Our research was interpretive and did not focus on generalisability. Instead, we looked at rich, contextual descriptions of participant experiences and meaning making [38]. However, the methods and findings of this study can be used to inform both the design process and design decisions of accessibility researchers and roboticists working with people with intellectual disabilities. A stimulating and playful environment that supports the creativity of participants is necessary for an inclusive co-design setting [40] and our Techshops provided this environment. The Techshops had elements that catered to diverse abilities of our participants and people were able to articulate their ideas without having to engage in abstract thought or read and write. Toolkits for creating like the one we provided can be used by people not trained in design so that they can imagine and express what they want the robots to do and what they look like. Generative toolkits are commonly employed in guided collaborative tasks when designing with people, and their outcomes such as artifacts and explanations or demonstrations of their application, can be examined to uncover fundamental trends [30]. The collage materials gave people the opportunity to create the type of robot they wanted to interact with in their chosen context and this gave insights to the research team about where people need support and the types of robots that can assist them in those contexts.

Generative AI platforms like Midjourney have been used to generate speculative designs and visually represent things that have not been brought into existence yet [23]. For people with intellectual disabilities who may have difficulty visualizing or imagining complex scenarios, generative AI tools like Midjourney can provide a visual representation of how their creations could exist in different settings. Many individuals with intellectual disabilities benefit from concrete, visual aids. Generative AI can take their ideas and transform them into tangible visual representations, making abstract concepts more understandable. It encourages creative exploration by enabling individuals to experiment with different combinations of images and contexts. The ideas generated through the collaging and use of generative AI may seem silly and impractical but attention to representations and narratives used in the design process is crucial to avoiding solutionism [9]. The participants were able to express how their ideal robot would support them in their chosen environment based on their previous experiences in these contexts. Absurdism and fragile fictions can open up space for more nuanced discussions of technological futures [9]. People value co-creation capabilities of generative AI as they can feel ownership over the creations and learn from the process [15]. Our participants requested printouts of the Midjourney outputs of their robots as they were proud of what they had co-created.

The role of the support workers in the co-design process cannot be understated. They assisted people to communicate their requirements and then to explain the features, communication modes and roles of their robots. In future research support workers should also be encouraged to design robots that can support them in their job, this will highlight their roles as both a proxy for the people they support and a co-user of the technology [6].

6 CONCLUSION

This study sought the perspectives of adults with intellectual disability on how robots could enhance their experiences in contexts of their choices, through a co-design approach in three phases. Our findings revealed that most of our participants preferred humanoid robots that were smaller than them. These robots had multiple forms of communication-like speech, sound, lights, gesture and music. Being able to have a say in low level actions and observe Alpha Mini recreate the interaction helped people visualise how their robot could behave. This supports the requirement for configurable robots. The most popular context was the supermarket which three people chose followed by the bank, garden and movie theatre which were the choice of two people each and the kitchen and bedroom had one each. All the robots had a purpose related to supporting an activity like shopping, taking money out of the ATM, cooking or cleaning. Six participants also stated that their robot could be a friend or companion to them as well. Future research can further explore co-designing multimodal interactions with robots by exploring different scenarios with participants in their chosen context. For example, going to the supermarket with them and being part of their grocery shopping experience to understand what a robot can do to assist them in the activity.

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