Supporting Autistic Children's Participation in Research Studies: A Mixed-Methods Study of

Familiarising Autistic Children with a Humanoid Robot

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Abstract

It is important that autism research is inclusive and supports the participation of a wide range of autistic people. However, there has been limited research on how to make studies accessible for autistic participants. This mixed-methods study explored how to promote the comfort of autistic children, using the specific example of visiting a research lab and meeting a humanoid robot. In Phase 1, fourteen parents of autistic children were interviewed about how their child could be made comfortable during a lab visit, including different approaches for familiarising their child with the robot. In Phase 2, autistic children of the parents in Phase 1 (n = 10) visited the lab and completed familiarisation activities with a humanoid robot. The opinions of the children and their parents about the children's experiences were recorded. Using reflexive thematic analysis, five overarching themes reflected how to best support autistic child participants. These themes encompassed elements of particular relevance to robot studies but also many practices of general relevance to participating in research: (1) Preparation is key, (2) Consideration of environmental factors, (3) Using familiarisation, (4) A supportive and engaged researcher, and (5) Individualised approaches. Based on our findings, we report preliminary and generalisable best-practice recommendations to support autistic children in a research setting and promote positive experiences.

Keywords: autism, robots, humanoid, familiarisation, participation

The importance of promoting inclusivity and positive experiences for autistic individuals who participate in research is becoming increasingly recognised (e.g., Gowen et al., 2019; Haas et al., 2016; Pellicano et al., 2017). Many autistic characteristics, such as sensory sensitivities (Yuan et al., 2022), the need for routine (Louis-Delsoin et al., 2024), and communication difficulties (Askari et al., 2015), may present as barriers to study participation. Co-occurring features, such as anxiety (e.g., van Steensel et al., 2011) and intolerance for uncertainty (e.g., Boulter et al., 2014), can also limit inclusion. Not only do researchers have a responsibility to ensure participation is as comfortable and as positive as possible, but inclusive research practices are key to ensuring that autism research is not limited to a narrow range of autistic people.

Guidance exists for researchers on how to promote the comfort of autistic participants during research participation. These recommendations include environmental considerations, such as considering the sensory environment and providing breaks during testing, as well as the provision of clear instructions, both on what will happen during the testing session and how to find the venue (Gowen et al., 2019). Guidelines framed specifically for autistic adults also highlight the importance of accessible consent processes and offering multiple modes of participation (Nicolaidis et al., 2019). Related to this is the recommended use of research passports, which can help autistic people communicate their needs and preferences to researchers (Ashworth et al., 2021). Researchers have also developed recommendations for working with autistic children who are nonverbal or who have intellectual disabilities, and stress the importance of monitoring participants' energy levels and paying attention to behavioural signs that the participant may not wish to continue testing (McKinney et al., 2021). However, existing insights and recommendations are based on surveys of the literature, reflections on researchers' own experiences, or

consultation with autistic adults or parents of autistic children of their previous experiences with research. To date, no research study has used preparation for or participation in a research study to directly generate insights from autistic people or family members.

Research involving children necessarily involves additional considerations compared to adult participants (Fargas-Malet et al., 2010), and this is particularly the case for children with additional needs. For autistic children, a relevant consideration is how they might experience the novel equipment that is often a feature of experimental studies. Autistic children are often invited to take part in studies that include specialist equipment, including neuroimaging (Rafiee et al., 2022), eye tracking (Papagiannopoulou et al., 2014), virtual reality (Chen et al., 2022), and robots (Alabdulkareem et al., 2022). Research with robots, particularly with a focus on human-robot interaction (HRI), has become increasingly popular in recent years. Robots are often favoured as a data collection tool because of the experimental control they afford (e.g., Chevalier et al., 2020; Giannopulu et al., 2014; Golliot et al., 2015). Human experimenters may send unintentional messages via subconscious modifications to their voice or facial expressions, but this can be tightly controlled in HRI studies (Huijnen et al., 2018). Other studies focus on HRI specifically, using robots in interventions to improve the wellbeing of autistic children (e.g., Boccanfuso et al., 2017; Fachantidis et al., 2020; Huijnen et al., 2021; Kajopoulos et al., 2015).

Autistic children can find meeting a novel robot in an experimental setting difficult, leading to discomfort, distress, and even participant withdrawal (Huijnen et al., 2021; Short et al., 2017). There are a range of factors that may make the experimental setting uncomfortable for autistic children. Many of these, including the disruption to routine and the introduction to unfamiliar people and settings, are generalisable to many types of study. However, there are likely additional challenges that occur when meeting an unfamiliar robot.

Indeed, researchers have identified the engineering challenge of designing robot interactions in a way that is both engaging and perceived as nonthreatening for children (Scassellati et al., 2012). Specific anxiety about the robot has been highlighted as a driver of discomfort in previous HRI studies with autistic children (e.g., Di Nuovo et al., 2020; Petric et al., 2017). Difficulties with tolerating the uncertainty of the robot's behaviours (e.g., Boulter et al., 2014) and sensory discomfort (e.g., Kirby et al., 2022) are additional factors that may be relevant.

Familiarisation phases are a potential way of helping autistic children overcome discomfort when meeting a robot. A familiarisation phase is an initial phase of an experiment designed to introduce participants to key aspects of the methodology, and is used in HRI research (Wallbridge et al., 2024). Previously, including a familiarisation phase in an HRI study reduced the withdrawal rate of autistic child participants from 87.5% to 10.5% (Petric et al., 2017), indicating they can have a significant impact. Our systematic review of the familiarisation strategies used by researchers to introduce autistic participants found that a wide variety of approaches were used (Wallbridge et al., 2024), such as showing the participant what the robot can do, or having the participant and the robot participate in an activity together. However, the majority of studies that reported using a familiarisation phase provided limited detail. As such, understanding of familiarisation approaches remains limited. Other researchers who use specialised equipment that would likely be unfamiliar to children, such as magnetic resonance imaging (MRI) scanners, have successfully taken steps to generate bespoke guidance for familiarising autistic children with their study equipment (Tziraki et al., 2021). Although familiarisation methods do exist within the field of HRI (Wallbridge et al., 2023), there has been no specific exploration of the success of these techniques, including the perspectives of parents and autistic children.

In the current study, our primary aim was to investigate how to promote the comfort and enjoyment of autistic children in research, using the specific example of meeting a humanoid robot in a laboratory setting. Other researchers who use specialised practices within a real world example, we wanted to generate nuanced and ecologically-valid insights that could complement previous consultation work (e.g., Gowen et al., 2019; Nicolaidis et al., 2019). Additionally, we wanted to focus on the voice of autistic children and their parents. As such, we used a two-phase, mixed-methods design that involved a preparatory interview and a study visit. In the first phase, we conducted online semi-structured interviews with parents to discuss how to promote their children's comfort in a research setting, alongside a more specific exploration of the suitability of various robot familiarisation techniques. In the second phase, their children visited our lab to meet a humanoid robot, giving opportunity to explore the effectiveness of different familiarisation methods. Both the parents and children provided feedback on the child's experience of meeting the robot.

Methods

Participants

Fourteen parents and their autistic child were recruited through an advertisement on social media. The children were aged 6-11 years old, had a clinical diagnosis of autism, and had no significant physical disability that would limit their ability to interact with a humanoid robot.

All parents participated in Phase 1, an online interview, and were invited to take part in Phase 2, which occurred in the lab an average of 11.2 days (SD = 7.7) after Phase 1. Ten of the fourteen parents took part with their autistic child in Phase 2. Three other children chose not to participate: one decided not to take part on the morning of the study, and two chose not to participate upon arrival at the lab, but before beginning the study.

Parents completed the lifetime version of the Social Communication Questionnaire (SCQ) (Rutter et al., 2003). Scores ranged from 18 to 36 (M = 25.8, SD = 6.1), with a score of 15 or higher indicating that a child might be autistic. While all parents reported in the SCQ that their children were "able to talk using short phrases or sentences", three parents answered that they were unable have a "to a to and fro 'conversation' with [their child] that involves taking turns or building on what [they] have said". Participant demographics for each phase of the study are shown in Table 1.

Table 1

Participant Demographics

Sample Characteristics	n	Range	Mean	SD
Phase 1 – Parents (n = 14)				
Gender				
Female	13			
Male	0			
Unknown	1			
Race/Ethnicity				
White British	11			
Mexican	1			
White and Black African	1			
Unknown	1			
Age (years)		31-44	37.3	3.2
Phase 2 – Parents (n = 10)				
Gender				
Female	9			
Male	0			
Unknown	1			
Race/Ethnicity				
White British	7			
Mexican	1			
White and Black African	1			
Unknown	1			
Age (years)		36-44	36.7	3.0
Phase 2 – Children (n = 10)				
Gender				

Female	2		
Male	7		
Unknown	1		
Race/Ethnicity			
White British	7		
Mexican	1		
Indian, White, and Black African	1		
Unknown	1		
Age (years)	6.4-11.3	8.8	1.5

Parents received a £15 shopping voucher for participating. Children received a certificate and a sticker. The study was approved by the Cardiff University School of Psychology Research Ethics Committee. Each parent provided written informed consent and children provided verbal assent.

Materials

Humanoid robot

We used a NAO robot from United Robotics Group, which is commonly used in studies with autistic participants (Wallbridge et al., 2024). NAO robots are 57.4 cm tall, with tactile sensors and speakers, and are capable of speech, movement, and playing music (Figure 1). They connect to a computer via Wi-Fi and are controlled using Choregraphe (Pot et al., 2009) software. Further details of the NAO robot can be found elsewhere (e.g., Puglisi et al., 2022). We named the NAO robot Russell and used male pronouns.

Figure 1

Humanoid robot NAO by SoftBank Robotics
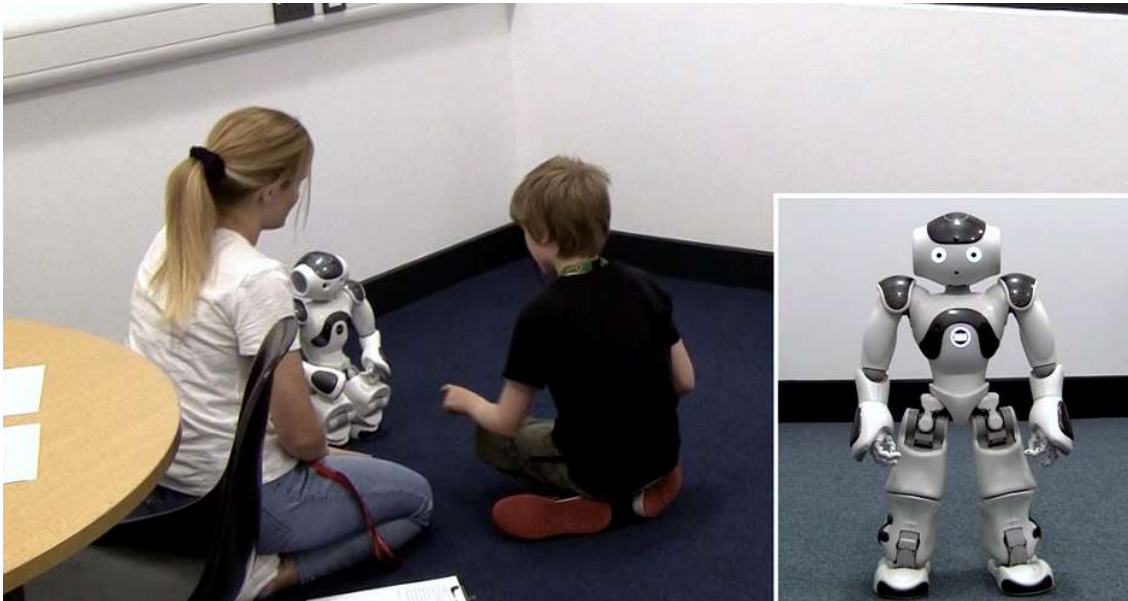
Note. A member of the research team and a child participant interacting with the NAO robot. A clearer photo of the NAO robot is shown on the right.

Familiarisation Approaches

The familiarisation approaches (see Table 2) were discussed with parents in the

Phase 1 interviews and used with the children in the Phase 2 lab visits. The approaches were

based on a subset of those identified in Wallbridge et al. (2023) that were considered

suitable for the NAO robot and/or the current method. These approaches were developed in

Choregraphe version 2.8.7.4 (Pot et al., 2009), and are available as part of a git repository.[1]

Additional details are located in the Supplementary Materials.

Capability Demonstration. This approach gradually displayed each of the robot's

capabilities, while the child watched passively. This was achieved by the robot conducting a

wake-up sequence (Part 1), which was followed by a song and dance routine (Part 2).

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[1] https://github.com/CWallbridge/Familiarisation

Stimulus and Response. This approach enabled two-way interactions between the robot and the child. Three different stimulus and response exchange options were available: a question and answer session, a following game where the child completed simple instructions given by the robot, and a mindful breathing exercise.

Static Exploration. This approach enabled the child to explore the robot using touch without the robot responding. Two types of Static Exploration were available: Free Exploration, in which the researcher invited the child to touch the robot, and Guided Exploration, in which the researcher guided the child through touching different parts of the robot in the context of giving the robot a "check-up".

Table 2

Familiarisation Approaches Discussed With Parents in the Phase 1 Interviews and Used With the Children in the Phase 2 Lab Visit

Familiarisation Approach	Description
Capability Demonstration	
Wake-Up Sequence	The robot gradually wakes up and introduces itself.
Song and Dance	The robot plays a song and does a dance along with it.
Stimulus and Response	
Question and Answer Session	The robot asks the child several questions, and also provides its own answers.
Following Game	The robot asks the child to do several simple movements.
Mindful Breathing	The robot leads the child through a mindful breathing exercise.
Static Exploration	

Free Exploration	The robot is "powered off" and the researcher invites the child to touch the robot.
Guided Exploration	The robot is "powered off" and the researcher asks the child to touch specific parts of the robot.

Phase 1 Parent Interview

A semi-structured online interview was conducted to explore parents' perspectives on how their child could be supported to visit our lab to meet a humanoid robot. Parents were shown a video of the NAO robot and its capabilities were described. The first part of the interview included a discussion of how the parent's child might feel about meeting the robot, alongside topics about how to promote the child's comfort during the visit. For the second part of the interview, parents were shown videos of the NAO robot enacting the Capability Demonstration (Wake-Up Sequence; Song and Dance) and Stimulus and Response. Static Exploration was described to parents verbally. Each familiarisation approach was followed by a discussion about how the parent thought their child would feel about the approach. For approaches that had multiple implementation options (e.g., Free Exploration or Guided Exploration), parents were asked to reflect on which option might best suit their child. The interview ended with a focus on parents' opinions about sharing information about their child's needs with researchers before a study, and how they thought this should be carried out.

Phase 2 Parent ratings and interview

Parents used Likert scales to indicate how comfortable they thought their child was during each familiarisation approach, and how much their child enjoyed each approach. At the end of the session, parents also reported how much their child enjoyed themselves

overall. All scales ranged from 1 to 5, with 1 representing the most negative response and 5 the most positive.

A semi-structured interview was also conducted with the parent in which they elaborated on their Likert scores. Questions were also asked about the appropriateness of the duration of each approach and the number of approaches used.

Phase 2 Child Interviews

Child participants were asked about their experience of spending time with the robot using three questions, answered using a 5-point Likert scale where 1 was the most negative response and 5 the most positive. The questions were, "Do you think Russell is friendly?", "Do you think Russell is happy?", and "How happy would you be to play with Russell again?". The first two questions were adapted from the Robotic Social Attributes Scale (Carpinella et al., 2017). Participants were first given three options and told to select the one they most agreed with (e.g., Friendly, In the middle, Unfriendly). If participants selected Friendly, then they were asked if they thought the robot was Very friendly or Just a little friendly. Analogous options were provided for Unfriendly, whereas In the middle was recorded as is. Answers could be expressed verbally, through pointing, or head shaking/nodding.

Children who could answer open-ended questions also completed a short semi-structured interview where they were asked about what they liked or disliked about the robot, what their favourite activity was (Song and Dance portion of the Capability Demonstration, Stimulus and Response approach, or Static Exploration), and what other games that the robot should learn to play. If open-ended questions were not accessible to a child, they were instead shown pictures representing the different activities and asked to point at their favourite activity, and any activities they did not like.

Procedure

The order of the different parts of the study is represented visually in Figure 2.

Phase 1 – Parent interview

Interviews were conducted online in Microsoft Teams by one of two researchers and lasted an average of 38 min (range: 28 min to 52 min). The interviews were recorded and transcribed. Researchers showed parents the familiarisation methods by sharing their screen and playing a pre-recorded video.

Phase 2 – Child and parent lab visit

As suggested by a parent in Phase 1, prior to the lab visit, each family was sent a storyboard that explained in simple terms what the child would be doing, accompanied by photographs. Parents could also request additional preparation materials during Phase 1. Two parents requested a video of the researchers introducing themselves, and another requested a letter from the researchers assuring the child that they were allowed to bring their comfort object.

During the lab visit, one researcher worked directly with the child while a second researcher operated the robot. Before entering the testing room, the child was shown a photograph of the robot and was given the opportunity to ask questions. Upon entering the room, the child could choose where they sat.

The child was then presented with the three familiarisation approaches in the order: Capability Demonstration, Stimulus and Response, Static Exploration. This fixed order was chosen as the level of interaction with the robot increases across the approaches. The specific implementation of each approach was predetermined in the Phase 1 parent interview. After all familiarisation approaches were completed, the researcher asked the child about their experience with the robot using Likert scales and the child interview.

During the child's session with the robot, their parent sat in an observation room

with the second researcher, where they observed the testing session through a one-way

mirror. Parents completed the Likert interviews regarding their child's perceived enjoyment

and comfort after each familiarisation approach. This was followed by the semi-structured

interview, which lasted an average of 11 min (range: 7 min to 15 min).

Figure 2

Order of Activities within the Study Phases
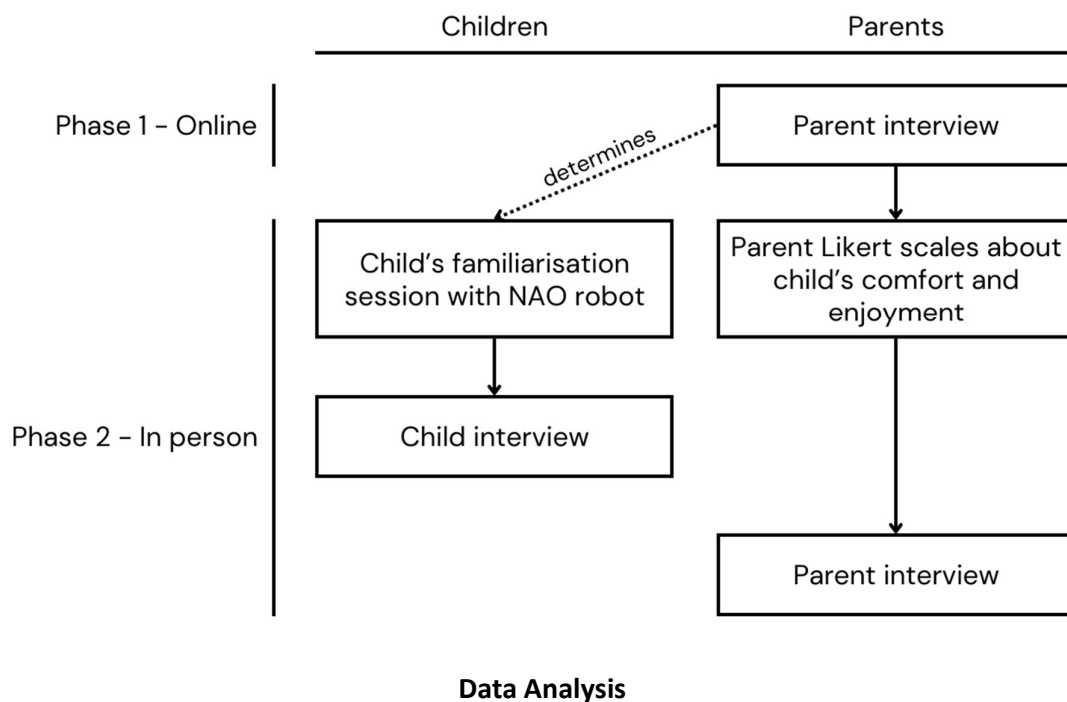
Data Analysis

Parents' semi-structured interviews in Phase 1 and Phase 2 were recorded and

automatically transcribed in Microsoft Teams, then later checked for accuracy and

anonymised. We used the method of thematic analysis to explore our data, drawing in

particular on the approach of reflexive thematic analysis (RTA; Braun & Clarke, 2021b). With

this method, we identified patterns and generated themes across both sets of interviews,

with information from transcripts of Phase 1 and Phase 2 treated with equal weight. The

pragmatic nature of our research aim, with its focus on what supports autistic children in a

research setting, informed our approach to the RTA. Our analysis was embedded in an experiential and realist framework, where we aimed to capture participant's perspectives and insights as directly expressed within the data. Aligned with this, our approach was inductive, meaning that our data coding and subsequent theme creation was driven by the data, rather than being shaped by pre-existing constructs about good research practices for autistic children. We focused on a semantic level of meaning in the data, which meant we explored what was being said directly rather than searching for latent, implicit meaning. An RTA approach also meant that our subjectivity and experiences with supporting autistic individuals were conceptualised as a useful tool to scaffold our understanding of the data, rather than as a threat to the validity of the results (Braun & Clarke, 2021a).

For the TA, two researchers independently coded all parent interview transcripts in NVivo 12 (Dhakal, 2022), coding in reverse order of one another. All interviews were double coded. Periodic checks were made to ensure consensus between coders, agreeing upon what data was relevant and how the codes should be labelled. Codes were then merged across the two coders to create a single dataset, with each coder independently merging half of the coded interviews. Where the codes used were different between coders, the coder selected the one that they considered most accurately represented the parents' comments. Both researchers refined the codes together, identifying and merging similar codes across the dataset. The coders then established initial thematic groupings together, which were further refined through discussion with the wider research team. Likert scales and child interviews were not integrated into the themes, and were analysed separately.

Both coders were non-autistic and were not parents. However, both coders were raised with autistic family members, and one had several years of experience working with autistic children, which meant they had professional experience of strategies for supporting

autistic children in daily life. One of the coders was not British and they were sensitive to the

possibility of cultural misreading. However, the collaborative coding strategy provided

reassurance. It was also reflected that one coder conducted most interviews while the other

did not collect any data; this created a balance between having a richer but more subjective

position and having a position of greater objectivity.

The use of two coders allowed exploration of different subjective interpretations of

the data, driven by distinct perspectives and backgrounds, enabling development of a richer

conceptualisation of participants' responses. Our pre-existing intention to develop

guidelines for researchers affected the framing of our themes as we wanted them to have

salience as potential action points. In generating information meant to be used by other

researchers, the two primary coders and the wider research team subjectively and

intentionally use their viewpoints as researchers to thematically interpret the dataset.

The children's answers to the open-ended questions in the interview were

transcribed and summarised; data were too limited for TA. The Likert scales for both parents

and children were explored using summary statistics.

Community involvement statement

Autistic community members were not involved in the development of this research study.

Results

Thematic analysis

Five main themes were generated from the parents' interviews: (1) Preparation is

key, (2) Consideration of environmental factors, (3) Using familiarisation, (4) A supportive

and engaged researcher, and (5) Individualised approaches. Four of the themes had distinct

subthemes. The relationships between the themes are depicted in Figure 3.

Figure 3

Thematic Map of Parents' Perspectives on How to Effectively Engage Autistic Children in Research with Humanoid Robots
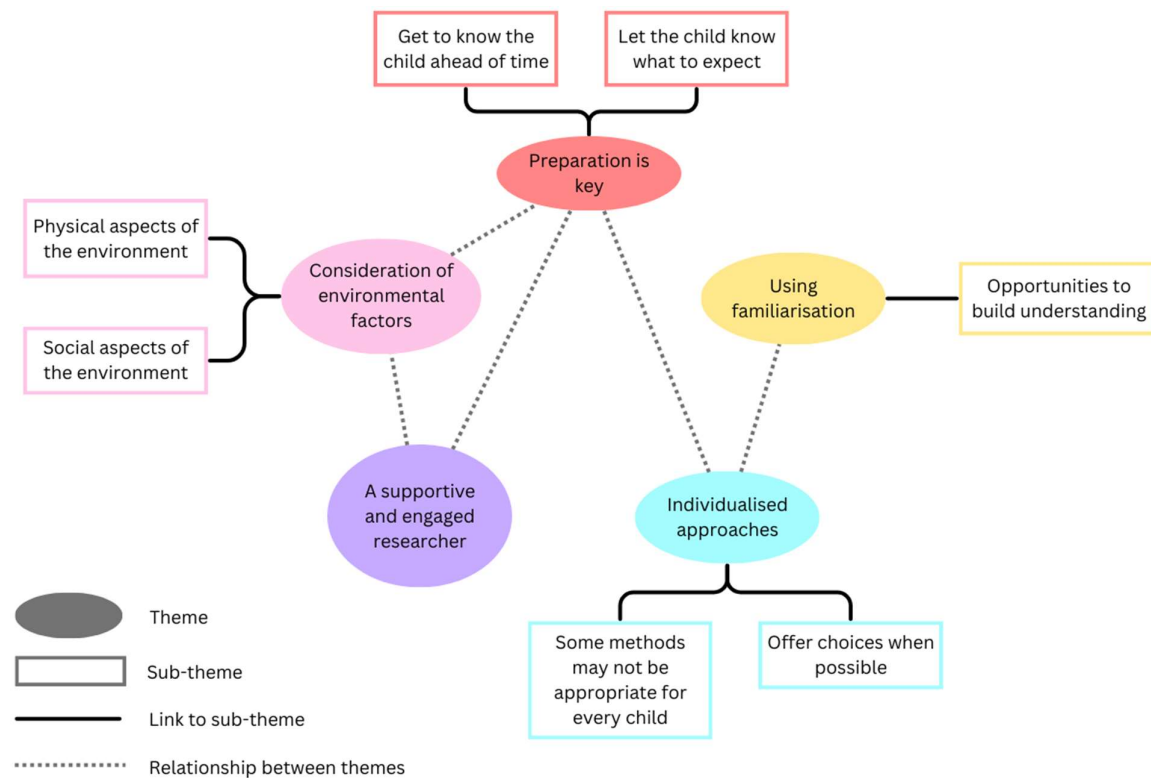
Preparation is key

Parents reflected that sharing information between the family and researchers before the child's visit was an important part of ensuring their child's comfort, because it helped the research team prepare for how to best support their child and gave the child a clearer idea of what to expect. Two subthemes were generated within this theme: *Get to know the child ahead of time*, and *Let the child know what to expect*.

Get to know the child ahead of time. Many parents explained that their child had differences in their communication style or additional conditions that impacted their

interactions (e.g., anxiety, ADHD, speech delay). Some offered guidance for how to

communicate with their child to help facilitate positive interactions:

> *[My child] communicates through a third person, so to speak, or he prefers to be told*
>
> *in the third person. So inside him, he has somebody called "Fluffy Puppy*". Now, if*
>
> *you want him to do something, if you ask Puppy to do it, he finds it far easier.*
>
> *- Parent #14*
>
> **This term has been anonymised*

Some parents reported that sensory sensitivities, anxieties, or fears could cause significant

distress for their child. A parent noted the importance of researchers knowing about these

before meeting their child:

> *I think it's better to do this 'cause you can kind of understand what's gonna frighten*
>
> *[my child].*
>
> *- Parent #8*

Let the child know what to expect. Many parents expressed that their child feels

anxious when dealing with the unknown. One parent explained a routine their child

regularly completed before going somewhere new:

> *He will look at videos of the place and what there is to do there, who is there, and*
>
> *what things look like . . . Otherwise . . . he's got to do that all before he actually gets*
>
> *through to what he needs to do.*
>
> *- Parent #14*

The storyboard each family received was cited by many as a valuable tool in helping prepare

their child. As one parent explained:

> *He was a bit, "What do I do? Wait, what is my purpose to be here?" When I read* [the
>
> storyboard] *it was like, "Oh, right, I'm here to have fun."*

- Parent #10

Some parents explained that it was important for them to have a complete understanding of what would happen, as it would enable them to help prepare their child.

Consideration of environmental factors

This theme was represented by two subthemes; parents thought that both physical and social environmental factors had the potential to make their child uncomfortable during their visit.

Physical aspects of the environment. Anxiety related to being in an unfamiliar space was a common concern among parents. Some indicated that this would be a greater source of anxiety for their child than the robot:

He might be less comfortable with the setting than the robot. The robot, he won't

have a problem with. It might just be the setting it's used in.

- Parent #10

Some parents also reported that visual aspects of the space, such as the room appearing too clinical, could cause their child to be nervous.

Social aspects of the environment. Interpersonal aspects of the study were another concern, particularly in relation to the child's anxiety around strangers. Many parents highlighted that their child found it difficult to effectively communicate with people they did not know.

He does struggle to speak to most people, unless he knows them really well. He kind

of shuts down and withdraws, and just kind of shakes his head. So he just gets really

anxious and nervous and doesn't know how to express himself properly.

- Parent #16

This relates closely to the theme *Preparation is key*, as some parents suggested this anxiety

might be reduced if their child could see photographs of the researchers before their visit.

Some parents said that their child may also feel self-conscious, awkward, or embarrassed if they sensed they were being watched. This was both in reference to the child being aware of their parent and a researcher observing them through a one-way mirror, and the sentiment that their child may feel embarrassed engaging in certain activities in the presence of any audience. One parent suggested that this feeling of awkwardness can be reduced by limiting the number of people who are observing the child.

Some parents commented that their child may feel more comfortable if their parent was in the testing room, providing a "familiar face". However, other parents said that their child might find this distracting:

. . . I think he's more likely to focus if I'm not there. So I've taken him to an optician's appointment, and because I was there, he got more distracted. He was trying to interact with me and not the optician.

- Parent #13

In summary, parents felt that there were several elements of the study environment unrelated to the robot that could impact how their child feels and behaves.

Using familiarisation

Parents viewed familiarisation as an important factor in promoting a successful study session, with many saying that their child would initially need time to "warm up" to the robot. Some parents also highlighted the importance the child forming a "connection" with the robot.

Some parents were less concerned about their child being anxious around the robot, and instead thought their child might lose interest in it. Potential causes included the child's short attention span, the robot being less responsive than expected, or robots not being one

of their child's interests. The duration of the familiarisation activities was therefore deemed an important consideration.

Ultimately, parents felt that taking part in a research study should be fun for their child. Some stressed this as being crucial, indicating that their child was resistant to participating in things they didn't enjoy.

> *Because [if] you mentioned school or homework . . . he just completely shuts down. But if he thinks it's gonna be fun, yeah, he'd be all for it and probably get really involved.*
>
> *- Parent #16*

Within this theme, there was one subtheme related to the benefits of increasing the child's understanding of the robot.

Opportunities to build understanding. Parents indicated that effective familiarisation methods were ones that built the child's understanding of the robot. Some parents highlighted activities that gave the child an opportunity to explore the robot on a mechanical level. Other parents stressed the importance of activities that showed the robot's capabilities or nature, saying their child may initially worry that the robot was unfriendly or dangerous:

> *He might be a little, like, daunted at first . . . because of the things we see about robots being like, good robots and bad robots . . . He'll probably get more comfortable when he realizes that it's not any sort of threat.*
>
> *- Parent #13*

In summary, parents thought it was important for the familiarisation session to build the child's trust and understanding in the robot, while still keeping them engaged.

A supportive and engaged researcher

Parents noted having a researcher lead their child through the interactions helped the child understand that it was safe for them to follow the robot's instructions. As one parent explained:

Notice that sort of about halfway through, [the researcher] didn't have to repeat what Russell said. [My child] was just going off what Russell said. So that's sort of like, a sort of gradual level of trust… "I can do it and nothing bad's gonna happen . . . It's safe to do."

- Parent #9

Similarly, some parents reported that their child may have been anxious about what they were allowed to do, such as how to touch the robot without damaging it, causing the child to be more cautious and reserved. Parents suggested that this could be overcome by having the researcher give explicit permission, clear boundaries, and demonstrate what to do.

This theme closely relates to the theme *Preparation is key*, as having a good understanding of the child's anxieties, communication style, and needs enables researchers to better support them during the study. It also relates to *Consideration of environmental factors*, as the research team has the potential to be a source of support for the child's anxiety.

Individualised approaches

Parents described that the most effective familiarisation method may depend on the child. There were two subthemes: *Some methods may not be appropriate for every child*, and *Offer choices when possible*.

Some methods may not be appropriate for every child. Many parents said some familiarisation options may not be appropriate for their child due to their age or perception

of their own maturity. One parent, when reflecting on the song choices, explained why they

chose the robot dance over the nursery rhyme options:

> *I think that he would think that the other two are quite babyish, and he thinks that*
>
> *he's a lot more grown-up than that.*
>
> *- Parent #4*

Others reported some methods would be too complex for their child, which could cause

them to lose interest in the robot. Similarly, many children experienced difficulties with

speech or movement, which that would make it difficult for them to complete certain tasks.

Some parents suggested their child would not need to experience all of the

familiarisation approaches, as they anticipated their child would feel comfortable around the

robot almost immediately. Conversely, others said that their child would need them all, and

may even need additional time with a particular activity, or more time with the robot in

general, to feel comfortable.

This subtheme is also closely related to the theme *Preparation is key*, as having this

information ahead of time enables researchers to make adjustments to the familiarisation

protocol where necessary.

Offer choices when possible. Parents suggested that, when possible, it would be

beneficial to let their child choose how they would like to interact with the robot. While this

was not the case for every child, many parents said that their child would feel comfortable

communicating their needs and preferences with the researchers. Parents also reflected on

the benefits of giving children choices in less formal ways. For example, children were

allowed to sit anywhere in the room during the study, whilst the robot remained stationary.

Parents said this enabled their child to choose how far away from the robot they would like

to be:

> *It's like staying in the one spot . . . He can move away if he needs to . . .*
>
> *- Parent #15*

In summary, individualised approaches were considered beneficial and reflected the children's abilities and preferences. This is closely related to the theme *Using familiarisation*, as the most appropriate way to acclimate each child to the robot varied.

Parent and Child Preferences

Phase 1 parent selection of familiarisation activities

The 14 parents who participated in the Phase 1 interview selected which Stimulus and Response and Static Exploration activities would be most appropriate for their child. The Following Game was the most common Stimulus and Response choice, and Guided Exploration was the most common Static Exploration choice (see Table 3).

Table 3

Parent's familiarisation choices during the Phase 1 pre-visit interview

Familiarisation Approach	Number of Parents
Stimulus and Response	
Following Game	9 (64%)
Question and Answer	4 (29%)
Mindful Breathing	1 (7%)
Static Exploration	
Guided Exploration	9 (64%)
Free Exploration	5 (36%)

Phase 2 parent and child preferences

Nine children completed all of the familiarisation approaches, whereas one child chose to end the familiarisation session after the Wake-Up Sequence. Their parent explained the child was eager to attend another activity. Children who completed all of the familiarisation activities were asked which activity was their favourite: the Song and Dance

portion of the Capability Demonstration segment, the Stimulus and Response activity, or the Static Exploration. The Stimulus and Response activity was the most popular choice amongst the children (Table 4). One child did not have a favourite activity.

The children's parents were asked which one approach would be the most helpful in familiarising their child with the robot. Similar to the children, the Stimulus and Response approach was the most popular choice amongst parents (Table 4).

Table 4

Parents' and Children's Preferred Familiarisation Activities in Phase 2

| Familiarisation Approach	Number of Participants
Children	
Stimulus and Response	4 (50%)
Capability Demonstration	3 (38%)
Static Exploration	1 (13%)
Parents	
Stimulus and Response	7 (78%)
Capability Demonstration	1 (13%)
Static Exploration	1 (13%)

Comfort and Enjoyment Ratings

Overall, parents rated their children as showing high levels of comfort with, and enjoyment of, the activities (Figure 4). Although statistical analysis was not appropriate with the small sample, both comfort and enjoyment improved for the group as a whole across the activities.
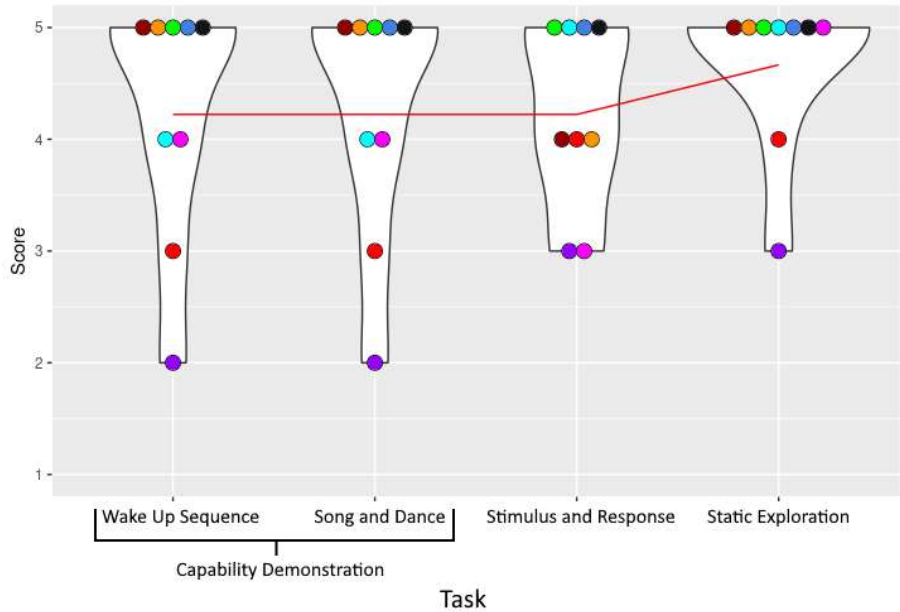
Figure 4

Parent Ratings of (a) Child Comfort and (b) Enjoyment During Each Familiarisation Activity in
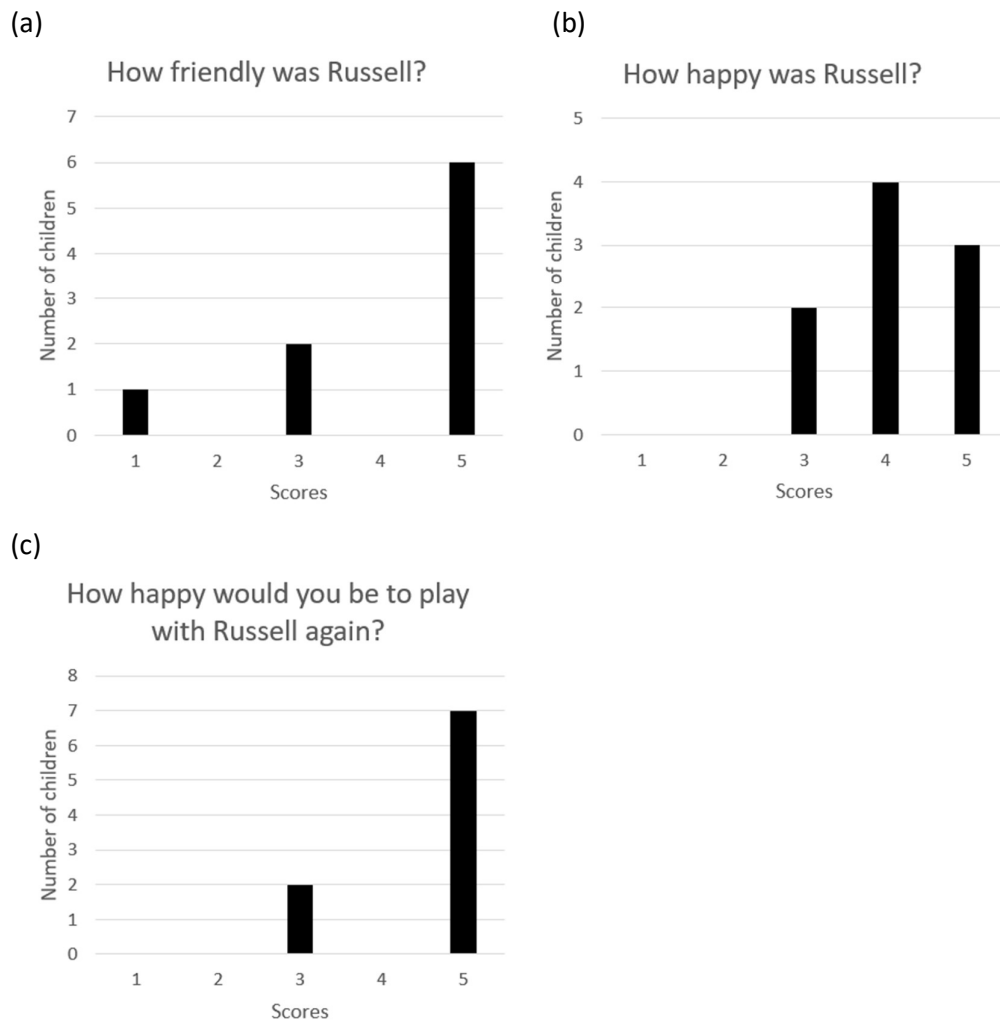
Phase 2

(a)
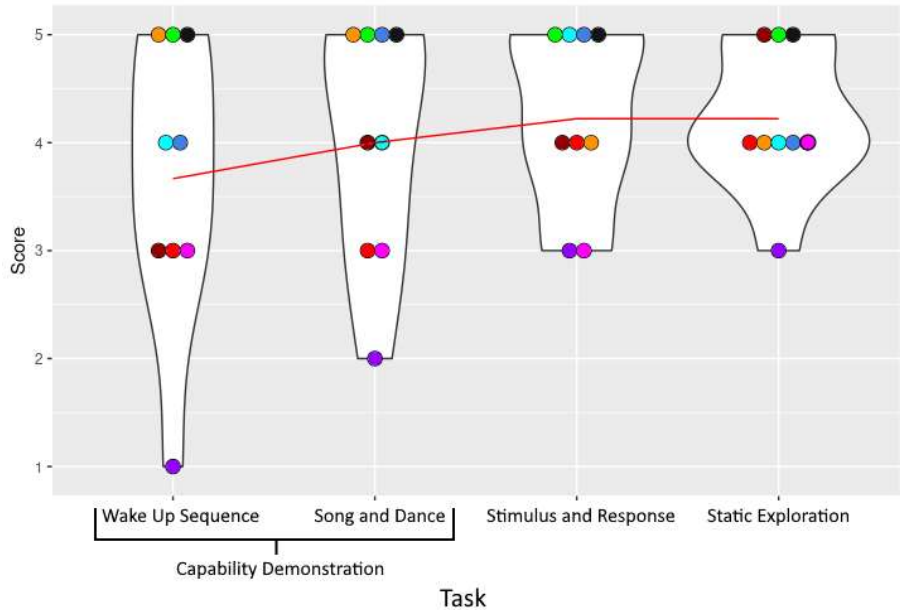
(b)

Note: Each colour represents an individual child. The line shows the mean scores. For scoring, 1 = very uncomfortable/did not enjoy and 5 = very comfortable/really enjoyed.

Children's Opinions About the Robot

Following familiarisation, children were asked to rate how friendly the robot was (mean score of 4.1 (SD = 1.45)), how happy the robot was (mean = 4.1 ± 0.78), and how happy they would be to play with the robot again (mean = 4.6 ± 0.88) (Figure 5). Some children found these questions difficult to answer. When asked if the robot was friendly, one child said, "I don't know what that means." Another, when asked if he thought the robot was happy, said "I can't really tell if he's happy." The researcher offered clarification and all children made selections.

Figure 5

Children's opinions about the robot in Phase 2

(a)

How friendly was Russell?

(b)

How happy was Russell?

(c)

How happy would you be to play with Russell again?

Note: For scoring, 1 = most negative and 5 = most positive response options.

Seven children were able to verbally answer open-ended questions and were asked about

what they liked/disliked about the robot. Children volunteered limited information, but most

responses were positive. Some children identified their favourite thing about the robot, with

responses encompassing specific features (his fingers, his waking up sequence, his dancing),

his mood ("very happy", "fun"), and generic endorsement ("everything"). Most children did

not identify anything they disliked about the robot, but one commented about the robot

being a bit loud when he talked. An additional child observed that the robot's gaze followed

them when they moved, which was "a little bit creepy".

Discussion

Using mixed-methods, we explored the most effective approaches for supporting the

comfort and enjoyment of autistic children when meeting a humanoid robot in a research

setting. Qualitative analysis of interviews with autistic children's parents identified five

themes regarding how to best support autistic children in a research setting, using the

specific example of meeting a humanoid robot: (1) Preparation is key, (2) Consideration of

environmental factors, (3) Using familiarisation, (4) A supportive and engaged researcher,

and (5) Individualised approaches. Additional qualitative and quantitative data indicated that

parents and children felt positively about the child's experience of meeting the robot and

our familiarisation techniques were successful. Synthesising across our findings, we present

a set of preliminary recommendations for researchers wanting to support the inclusion of

autistic children in research.

In our investigation of research inclusion for autistic children, we explored three

different approaches for familiarising autistic children with a humanoid robot. Across

qualitative and quantitative measurements, all familiarisation methods were well received

and can be recommended for use with autistic children, depending on the child's needs and

the study requirements. Parents and children were generally well aligned in their

preferences for different familiarisation approaches. Children preferred the Stimulus and

Response and Capability Demonstration approaches over the Static Exploration, and parents

showed a strong preference for Stimulus and Response activities. The Stimulus and

Response approach was unique in that it elicited two-way interactions between the child

and the robot, which may be an important factor. Static Exploration, which could be very

open-ended and relatively un-scaffolded, was the least preferred and may reflect the

preference for routine in autistic people (e.g., Leekam et al., 2011). However, the fixed order

of the approaches, chosen to enable a graded introduction, may have influenced opinions.

One consideration when recommending our familiarisation techniques is how

generalisable they would be to studies using other robots. However, the familiarisation

approaches used in the current study were drawn from a previous systematic review of

studies that collectively used 28 different models of robots with autistic participants

(Wallbridge et al., 2024). Further, the majority of studies did not use the NAO robot, as used

in the current study. As such, the techniques are likely to be applicable to other robots being

used in research. However, the specific execution of our familiarisation techniques will

depend on the capabilities of the robot and some adaptations may be required (e.g. if the

robot cannot play music). Similarly, the specific features of the robot (e.g. quality of sound;

fluidity of movement) may enhance or inhibit the impact of certain familiarisation

approaches.

Despite humanoid robots potentially being a source of discomfort for autistic

children (Wallbridge et al., 2024), they include properties that may be particularly appealing.

Indeed, many autistic children find meeting a robot positive (e.g., Garnier et al., 2023). Both

autistic adults and educators of autistic children have highlighted that the consistent and

predictable nature of robots, compared to the complexity of human interaction, may make

them attractive to autistic children (Alcorn et al., 2019; Silvera-Tawil et al., 2022). Educators

also recognised that robots could be inherently engaging to autistic children (Alcorn et al.,

2019). Further, although robots may contain sensory features that some autistic children

find difficult, these can invariably be adjusted to suit the child's needs (e.g., Kumazaki et al.,

2022). Thus, arguably, the role of the familiarisation phase is to convey these appealing

properties to an autistic child, so that initial uncertainty and wariness can be replaced by confidence in the parameters of the robot.

   While parents typically found the familiarisation approaches to be effective, they also stressed the importance of beginning the familiarisation process before the lab visit. Parents' reports that their children benefit from having comprehensive information ahead of time is consistent with the perspectives of autistic adults, who also value pre-study information (Gowen et al., 2019). In the current study, a parent specifically suggested we use a storyboard to explain the laboratory visit to their child, and this was used with all children. Building from this, we recommend a digestible introduction to the study is given to all child participants. This could take the form of Social Stories™ (Gray & Garand, 1993), an existing storyboard framework that is widely used (Qi et al., 2018). However, our data also indicated that parents should be encouraged to suggest specific preparatory materials that may support their child (e.g., a letter that allays a concern). Supplementing introductory materials with photos and videos, framed in the context of "What to expect", were considered useful by autistic adult participants (Gowen et al., 2019). This highlights that many needs will not be age-specific, although approaches must be age-appropriate. The benefit of preparatory materials likely reflects the elevated intolerance of uncertainty (Boulter et al., 2014; Wigham et al., 2015) and anxiety (MacNeil et al., 2009) often seen in autistic people.

   Although a humanoid robot was the focus of the current study, many other studies also use novel equipment that may be difficult for autistic children. For example, sources of discomfort for autistic children in the MRI scanning environment were similar to those identified in the current study, including sensitivity to loud noises and being in an unfamiliar space (Tziraki et al., 2021). Tziraki et al. identified techniques that could help introduce

autistic children to an MRI scanner that have resonance with our own findings, including

learning about each child's communication style and providing families with preparatory

materials. However, some techniques reflected the specific challenges of the equipment,

such as showing children a miniature "toy" MR scanner and listening to the scanner noise in

advance of the scanning session. These findings highlight that there will be shared sources of

potential discomfort across most experimental studies, alongside study-specific

considerations. Indeed, although the focus of our qualitative interview with parents was

about familiarising autistic children with a humanoid robot, discussion of the study visit

elicited many comments that reflected general study features. These included the potential

challenge of meeting unfamiliar people and being in an unfamiliar place. Researchers should

therefore consider both the general and study-specific elements of their research when

preparing autistic children and families for a research study.

Expanding on the wider relevance of the current study, many of the approaches we

identified are applicable outside of research contexts. Autistic children may encounter

robots or other novel equipment in clinical or educational settings (Huijnen et al., 2017;

Saleh et al., 2020), with negative reactions to meeting a humanoid robot documented in

both classroom and clinical settings (e.g., Di Nuovo et al., 2020; Garnier et al., 2023).

Introductions to robots may need to be different in applied contexts, for example, managing

expectations about access to the robot in the classroom (Silvera-Tawil et al., 2022). However,

many of the fundamental principles described in the current study will be applicable to

these settings.

Many of the parents we interviewed indicated that their child might struggle with

aspects of the study because of characteristics that were not directly related to being

autistic. Several children experienced co-occurring difficulties, including attentional

difficulties, specific fears, and anxiety. The high prevalence and wide range of additional diagnoses and/or traits in autistic populations (Bougeard et al., 2021; Rodriguez-Seijas et al., 2020; Rosen et al., 2018) further exemplify the importance of learning about each child before they participate in a study. Utilising existing frameworks such as research passports (Ashworth et al., 2021) can support this aim of enabling autistic participants to share their needs and preferences with researchers. While autistic children may need familiarisation more than other groups, the diversity of children's needs make it likely that *all* children would respond positively to tailored approaches to promote their comfort and enjoyment while participating in research.

Recommendations

Utilising themes that were generated from parent interviews, we have developed a set of recommendations for promoting the comfort of autistic children in research settings (Table 5). As illustrated in Table 5, each recommendation draws from one of the themes we generated through RTA. Reflecting our data, the recommendations are focused on steps that can be taken before the testing phase of the study. Importantly, the recommendations are not specific to studies that include robots, but are broadly applicable to studies with autistic children. Many of our suggestions complement recommendations offered by Gowen et al. (2019) on how to make studies more accessible for autistic participants, particularly how to prepare participants and selecting comfortable, sensory-friendly testing spaces.

Table 5

Recommendations for Supporting Autistic Children in Research Settings based on Themes
Generated *from the Current Study*

		Description	Associated Theme
1	Testing Space	Choose a testing space that is child-friendly and that avoids common sensory triggers, such as bright lights or loud background noise.	Consideration of environmental factors
2	Learn About the Participant	Provide an opportunity for parents to share information about their child before the study session.	Preparation is key
3	Adjust Protocol	Adjust the familiarisation and study protocol based on the information received from the parents.	Individualised approaches
4	Preparation Materials	Send families preparation materials to help the children better understand what to expect when they come for the study.	Preparation is key
5	Supportive Researcher	Have a member of the research team present who is prepared to support the child throughout the study.	A supportive and engaged researcher

Limitations and future directions

In the current study, the preparation materials sent to families prior to the lab visit prepared most children for their familiarisation sessions, but three children did not want to visit the lab for the study. This suggests that more work is needed to identify the most effective preparation materials.

Additional work can also be done to collect richer feedback from autistic children. We used simple questions to be inclusive of children with limited verbal communication. However, this approach limited the depth of feedback gained from children with more

advanced communication abilities. In future, a tiered approach, where the data collected

from children is adapted to suit their abilities, may enable children to be better represented.

There are also creative qualitative methods that can be used to interview autistic children,

including more visual and embodied child-led interviews (Lewis et al., 2023). It is likely that

these approaches would have enabled better inclusivity of children with alternative

communication styles or more limited receptive language.

　　Expanding on the appropriateness of the child questions, two children found it

difficult to decide how happy or friendly the robot was. These questions were adapted from

an existing questionnaire about how people perceive robots (Carpinella et al., 2017).

However, autistic children often understand or define friendships differently than non-

autistic children (Petrina et al., 2014), which may have explained the challenges some

children experienced. It is also unknown whether the perceived happiness or friendliness of

a robot are key factors in influencing how much autistic children like robots. Additional

research is needed to determine what attributes of robots influence autistic children's

opinions. This will enable researchers to more accurately evaluate robots' interactions in

accordance with what is important to autistic children.

　　The current study was not an exhaustive exploration of familiarisation methods that

have been used in research with autistic children and humanoid robots (see Wallbridge et

al., 2023), and only one type of robot was used. Further research is needed to evaluate the

effectiveness of other approaches across a wider range of robots.

Conclusion

　　Using mixed-methods, we worked with parents and autistic children to determine

how to promote children's comfort and wellbeing during research, using the specific

example of a laboratory visit to meet a humanoid robot. We found that our robot

familiarisation methods were well received, and also gained valuable insights into

generalisable techniques for supporting positive participant experiences. We have

summarised our findings into a set of general recommendations that we hope will support

future researchers in delivering inclusive research with autistic children.

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References

Alabdulkareem, A., Alhakbani, N., & Al-Nafjan, A. (2022). A Systematic Review of Research on Robot-Assisted Therapy for Children with Autism. *Sensors*, *22*(3), Article 3. https://doi.org/10.3390/s22030944

Alcorn, A. M., Ainger, E., Charisi, V., Mantinioti, S., Petrović, S., Schadenberg, B. R., Tavassoli, T., & Pellicano, E. (2019). Educators' Views on Using Humanoid Robots With Autistic Learners in Special Education Settings in England. *Frontiers in Robotics and AI*, *6*, 107. https://doi.org/10.3389/frobt.2019.00107

Ashworth, M., Crane, L., Steward, R., Bovis, M., & Pellicano, E. (2021). Toward Empathetic Autism Research: Developing an Autism-Specific Research Passport. *Autism in Adulthood: Challenges and Management*, *3*(3), 280–288. https://doi.org/10.1089/aut.2020.0026

Askari, S., Anaby, D., Bergthorson, M., Majnemer, A., Elsabbagh, M., & Zwaigenbaum, L. (2015). Participation of Children and Youth with Autism Spectrum Disorder: A Scoping Review. *Review Journal of Autism and Developmental Disorders*, *2*(1), 103–114. https://doi.org/10.1007/s40489-014-0040-7

Boccanfuso, L., Scarborough, S., Abramson, R. K., Hall, A. V., Wright, H. H., & O'Kane, J. M. (2017). A low-cost socially assistive robot and robot-assisted intervention for children with autism spectrum disorder: Field trials and lessons learned. *Autonomous Robots*, *41*(3), 637–655. https://doi.org/10.1007/s10514-016-9554-4

Bougeard, C., Picarel-Blanchot, F., Schmid, R., Campbell, R., & Buitelaar, J. (2021). Prevalence of Autism Spectrum Disorder and Co-morbidities in Children and Adolescents: A Systematic Literature Review. *Frontiers in Psychiatry*, *12*. https://doi.org/10.3389/fpsyt.2021.744709

Boulter, C., Freeston, M., South, M., & Rodgers, J. (2014). Intolerance of uncertainty as a framework for understanding anxiety in children and adolescents with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *44*(6), 1391–1402. https://doi.org/10.1007/s10803-013-2001-x

Boyatzis, R. E. (1998). *Transforming Qualitative Information: Thematic Analysis and Code Development*. SAGE.

Braun, V., & Clarke, V. (2021a). Can I use TA? Should I use TA? Should I not use TA? Comparing reflexive thematic analysis and other pattern-based qualitative analytic approaches. *Counselling and Psychotherapy Research*, *21*(1), 37–47. https://doi.org/10.1002/capr.12360

Braun, V., & Clarke, V. (2021b). *Thematic Analysis: A Practical Guide*. SAGE.

Carpinella, C., Wyman, A., Perez, M., & Stroessner, S. (2017). *The Robotic Social Attributes Scale (RoSAS): Development and Validation*. 254–262. https://doi.org/10.1145/2909824.3020208

Chen, J., Hu, J., Zhang, K., Zeng, X., Ma, Y., Lu, W., Zhang, K., & Wang, G. (2022). Virtual reality enhances the social skills of children with autism spectrum disorder: A review. *Interactive Learning Environments*, *0*(0), 1–22. https://doi.org/10.1080/10494820.2022.2146139

Chevalier, P., Kompatsiari, K., Ciardo, F., & Wykowska, A. (2020). Examining joint attention with the use of humanoid robots-A new approach to study fundamental mechanisms of social cognition. *Psychonomic Bulletin & Review*, *27*(2), 217–236. https://doi.org/10.3758/s13423-019-01689-4

Dhakal, K. (2022). NVivo. *Journal of the Medical Library Association : JMLA*, *110*(2), 270–272. https://doi.org/10.5195/jmla.2022.1271

Di Nuovo, A., Bamforth, J., Conti, D., Sage, K., Ibbotson, R., Clegg, J., Westaway, A., & Arnold, K. (2020). An Explorative Study on Robotics for Supporting Children with Autism Spectrum Disorder during Clinical Procedures. *Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction*, 189–191. https://doi.org/10.1145/3371382.3378277

Fachantidis, N., Syriopoulou-Delli, C. K., & Zygopoulou, M. (2020). The effectiveness of socially assistive robotics in children with autism spectrum disorder. *International Journal of Developmental Disabilities*, *66*(2), 113–121. https://doi.org/10.1080/20473869.2018.1495391

Fargas-Malet, M., McSherry, D., Larkin, E., & Robinson, C. (2010). research with children: Methodological issues and innovative techniques. *Journal of Early Childhood Research*, *8*(2), 175–192. https://doi.org/10.1177/1476718X09345412

Garnier, P., Martel, K., Dachez, J., Audry, P., Bourgoin, P., & Stawinski, F. (2023). Educators' perspectives on working with a humanoid robot in a French preschool class for autistic children. *Journal of Research in Special Educational Needs*, *23*(3), 163–174. https://doi.org/10.1111/1471-3802.12588

Giannopulu, I., Montreynaud, V., & Watanabe, T. (2014). PEKOPPA: A minimalistic toy robot to analyse a listener-speaker situation in neurotypical and autistic children aged 6 years. *Proceedings of the Second International Conference on Human-Agent Interaction*, 9–16. https://doi.org/10.1145/2658861.2658872

Golliot, J., Raby-Nahas, C., Vezina, M., Merat, Y.-M., Beaudoin, A.-J., Couture, M., Salter, T., Côté, B., Duclos, C., Lavoie, M., & Michaud, F. (2015). A Tool to Diagnose Autism in Children Aged Between Two to Five Old: An Exploratory Study with the Robot QueBall. *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction Extended Abstracts*, 61–62. https://doi.org/10.1145/2701973.2701975

Gowen, E., Taylor, R., Bleazard, T., Greenstein, A., Baimbridge, P., & Poole, D. (2019). Guidelines for conducting research studies with the autism community. *Autism Policy & Practice*, *2*(1 A new beginning), 29–45.

Gray, C. A., & Garand, J. D. (1993). Social Stories: Improving Responses of Students with Autism with Accurate Social Information. *Focus on Autistic Behavior*, *8*(1), 1–10. https://doi.org/10.1177/108835769300800101

Guest, G., MacQueen, K. M., & Namey, E. E. (2011). *Applied Thematic Analysis*. SAGE Publications.

Haas, K., Costley, D., Falkmer, M., Richdale, A., Sofronoff, K., & Falkmer, T. (2016). Factors Influencing the Research Participation of Adults with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, *46*(5), 1793–1805. https://doi.org/10.1007/s10803-016-2708-6

Huijnen, C. A. G. J., Lexis, M. A. S., & De Witte, L. P. (2017). Robots as New Tools in Therapy and Education for Children with Autism. *International Journal of Neurorehabilitation*, *04*(04). https://doi.org/10.4172/2376-0281.1000278

Huijnen, C. A. G. J., Lexis, M. A. S., Jansens, R., & de Witte, L. P. (2018). Roles, Strengths and Challenges of Using Robots in Interventions for Children with Autism Spectrum Disorder (ASD). *Journal of Autism and Developmental Disorders*, 1–11. http://dx.doi.org/10.1007/s10803-018-3683-x

Huijnen, C. A. G. J., Verreussel-Willen, H. A. M. D., Lexis, M. A. S., & de Witte, L. P. (2021). Robot KASPAR as Mediator in Making Contact with Children with Autism: A Pilot Study. *International Journal of Social Robotics*, *13*(2), 237–249. https://doi.org/10.1007/s12369-020-00633-0

Kajopoulos, J., Wong, A. H. Y., Yuen, A. W. C., Dung, T. A., Kee, T. Y., & Wykowska, A. (2015). Robot-Assisted Training of Joint Attention Skills in Children Diagnosed with Autism. In A. Tapus, E. André, J.-C. Martin, F. Ferland, & M. Ammi (Eds.), *Social Robotics* (pp. 296–305). Springer International Publishing. https://doi.org/10.1007/978-3-319-25554-5_30

Kirby, A. V., Bilder, D. A., Wiggins, L. D., Hughes, M. M., Davis, J., Hall-Lande, J. A., Lee, L.-C., McMahon, W. M., & Bakian, A. V. (2022). Sensory features in autism: Findings from a large population-based surveillance system. *Autism Research*, *15*(4), 751–760. https://doi.org/10.1002/aur.2670

Kumazaki, H., Muramatsu, T., Yoshikawa, Y., Matsumoto, Y., Kuwata, M., Takata, K., Ishiguro, H., & Mimura, M. (2022). Differences in the Optimal Motion of Android Robots for the Ease of Communications Among Individuals With Autism Spectrum Disorders. *Frontiers in Psychiatry*, *13*. https://doi.org/10.3389/fpsyt.2022.883371

Leekam, S. R., Prior, M. R., & Uljarevic, M. (2011). Restricted and repetitive behaviors in autism spectrum disorders: A review of research in the last decade. *Psychological Bulletin*, *137*(4), 562–593. https://doi.org/10.1037/a0023341

Lewis, K., Hamilton, L. G., & Vincent, J. (2023). Exploring the experiences of autistic pupils through creative research methods: Reflections on a participatory approach. *Infant and Child Development*, *n/a*, e2467. https://doi.org/10.1002/icd.2467

Louis-Delsoin, C., Morales, E., Ruiz Rodrigo, A., & Rousseau, J. (2024). Exploring the home environment of adults living with autism spectrum disorder: A qualitative study. *International Journal of Developmental Disabilities*, *70*(2), 213–224. https://doi.org/10.1080/20473869.2022.2071103

MacNeil, B. M., Lopes, V. A., & Minnes, P. M. (2009). Anxiety in children and adolescents with Autism Spectrum Disorders. *Research in Autism Spectrum Disorders*, *3*(1), 1–21. https://doi.org/10.1016/j.rasd.2008.06.001

McKinney, A., Weisblatt, E. J., Hotson, K. L., Ahmed, Z. B., Dias, C., BenShalom, D., Foster, J., Murphy, S., Villar, S. S., & Belmonte, M. K. (2021). Overcoming hurdles to intervention studies with autistic children with profound communication difficulties and their families. *Autism*, *25*(6), 1627. https://doi.org/10.1177/1362361321998916

Nicolaidis, C., Raymaker, D., Kapp, S. K., Baggs, A., Ashkenazy, E., McDonald, K., Weiner, M., Maslak, J., Hunter, M., & Joyce, A. (2019). The AASPIRE practice-based guidelines for the inclusion of autistic adults in research as co-researchers and study participants. *Autism*, *23*(8), 2007–2019. https://doi.org/10.1177/1362361319830523

Papagiannopoulou, E. A., Chitty, K. M., Hermens, D. F., Hickie, I. B., & Lagopoulos, J. (2014). A systematic review and meta-analysis of eye-tracking studies in children with autism spectrum disorders. *Social Neuroscience*, *9*(6), 610–632. https://doi.org/10.1080/17470919.2014.934966

Pellicano, E., Crane, L., & Gaudion, K. (2017). *Participatory autism research: A starter pack*. London: UCL Institute of Education. https://issuu.com/crae.ioe/docs/crane-starterpack_pages_v5

Petric, F., Miklić, D., Cepanec, M., Cvitanović, P., & Kovačić, Z. (2017). Functional imitation task in the context of robot-assisted Autism Spectrum Disorder diagnostics: Preliminary investigations. *2017 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, 1471–1478. https://doi.org/10.1109/ROMAN.2017.8172498

Petrina, N., Carter, M., & Stephenson, J. (2014). The nature of friendship in children with autism spectrum disorders: A systematic review. *Research in Autism Spectrum Disorders*, *8*(2), 111–126. https://doi.org/10.1016/j.rasd.2013.10.016

Pot, E., Monceaux, J., Gelin, R., & Maisonnier, B. (2009). Choregraphe: A graphical tool for humanoid robot programming. *RO-MAN 2009 - The 18th IEEE International Symposium on Robot and Human Interactive Communication*, 46–51. https://doi.org/10.1109/ROMAN.2009.5326209

Puglisi, A., Caprì, T., Pignolo, L., Gismondo, S., Chilà, P., Minutoli, R., Marino, F., Failla, C., Arnao, A. A., Tartarisco, G., Cerasa, A., & Pioggia, G. (2022). Social Humanoid Robots for Children with Autism Spectrum Disorders: A Review of Modalities, Indications, and Pitfalls. *Children*, *9*(7), Article 7. https://doi.org/10.3390/children9070953

Qi, C. H., Barton, E. E., Collier, M., Lin, Y.-L., & Montoya, C. (2018). A Systematic Review of Effects of Social Stories Interventions for Individuals With Autism Spectrum Disorder. *Focus on Autism and Other Developmental Disabilities*, *33*(1), 25–34. https://doi.org/10.1177/1088357615613516

Rafiee, F., Rezvani Habibabadi, R., Motaghi, M., Yousem, D. M., & Yousem, I. J. (2022). Brain MRI in Autism Spectrum Disorder: Narrative Review and Recent Advances. *Journal of Magnetic Resonance Imaging*, *55*(6), 1613–1624. https://doi.org/10.1002/jmri.27949

Rodriguez-Seijas, C., Gadow, K. D., Rosen, T. E., Kim, H., Lerner, M. D., & Eaton, N. R. (2020). A transdiagnostic model of psychiatric symptom co-occurrence and autism spectrum disorder. *Autism Research*, *13*(4), 579–590. https://doi.org/10.1002/aur.2228

Rosen, T. E., Mazefsky, C. A., Vasa, R. A., & Lerner, M. D. (2018). Co-occurring psychiatric conditions in autism spectrum disorder. *International Review of Psychiatry*, *30*(1), 40–61. https://doi.org/10.1080/09540261.2018.1450229

Rutter, M., Bailey, A., & Lord, C. (2003). *The social communication questionnaire: Manual*. Western Psychological Services.

Saleh, M. A., Hashim, H., Mohamed, N. N., Almisreb, A. A., & Durakovic, B. (2020). Robots and autistic children: A review. *Periodicals of Engineering and Natural Sciences*, *8*(3), Article 3. https://doi.org/10.21533/pen.v8i3.1457

Scassellati, B., Admoni, H., & Matarić, M. (2012). Robots for Use in Autism Research. *Annual Review of Biomedical Engineering*, *14*(1), 275–294. https://doi.org/10.1146/annurev-bioeng-071811-150036

Short, E. S., Deng, E. C., Feil-Seifer, D. J., & Mataric, M. J. (2017). Understanding Agency in Interactions Between Children With Autism and Socially Assistive Robots. *Https://Doi.Org/10.5898/JHRI.6.3.Short*. https://doi.org/10.5898/JHRI.6.3.Short

Silvera-Tawil, D., Bruck, S., Xiao, Y., & Bradford, D. (2022). Socially-Assistive Robots to Support Learning in Students on the Autism Spectrum: Investigating Educator Perspectives and a Pilot Trial of a Mobile Platform to Remove Barriers to Implementation. *Sensors*, *22*(16), Article 16. https://doi.org/10.3390/s22166125

Tziraki, M., Garg, S., Harrison, E., Wright, N. B., Hawkes, R., Akhtar, K., Green, J., & Stivaros, S. (2021). A Neuroimaging Preparation Protocol Tailored for Autism. *Autism Research*, *14*(1), 65–74. https://doi.org/10.1002/aur.2427

van Steensel, F. J. A., Bögels, S. M., & Perrin, S. (2011). Anxiety disorders in children and adolescents with autistic spectrum disorders: A meta-analysis. *Clinical Child and Family Psychology Review*, *14*(3), 302–317. https://doi.org/10.1007/s10567-011-0097-0

Wallbridge, C. D., McGregor, C., Drozdz, N., von dem Hagen, E., & Jones, C. R. G. (2024). A Systematic Review of Familiarisation Methods Used in Human–Robot Interactions for Autistic Participants. *International Journal of Social Robotics*, *16*(1), 37–53. https://doi.org/10.1007/s12369-023-01015-y

Wigham, S., Rodgers, J., South, M., McConachie, H., & Freeston, M. (2015). The Interplay Between Sensory Processing Abnormalities, Intolerance of Uncertainty, Anxiety and Restricted and Repetitive Behaviours in Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *45*(4), 943–952. https://doi.org/10.1007/s10803-014-2248-x

Yuan, H.-L., Lai, C. Y. Y., Wong, M. N. K., Kwong, T. C., Choy, Y. S., Mung, S. W. Y., & Chan, C. C. H. (2022). Interventions for Sensory Over-Responsivity in Individuals with Autism Spectrum Disorder: A Narrative Review. *Children (Basel, Switzerland)*, *9*(10), 1584. https://doi.org/10.3390/children9101584

Supplementary Materials

Further explanations of the procedures for the familiarisation approaches can be found below. These include the actions performed by both the robot and the researcher.

Capability Demonstration

Wake-Up Sequence

The first portion of the Capability Demonstration presented the robot's basic movement, auditory, and light functions in the context of the robot "waking up". It lasted approximately 70 s.

To mimic the robot being turned off or "asleep", the robot is seated in a kneeling position on the floor. Its LED lights are turned off, and it does not move or make any noise. The researcher and the child enter the room, and the researcher says, "Thank you for coming in to help us today. This is our robot, Russell. We'll have you play some games with Russell, then I'll ask you a few questions at the end when we're done to see what you thought about him. Does that sound okay?" After the child agrees, the researcher asks, "Is it alright if I turn Russell on now?"

Once the researcher has the child's consent to begin, the researcher taps the sensor on the robot's head to trigger the sequence shown in Table S1.

Table S1

Steps of the Wake-Up Sequence

Step	Details
Eye blinking	The robot's LED eye lights "blink" as if warming up, then turn on permanently. This takes approximately 12 seconds.
Musical sequence 1	The robot plays a short musical sequence (E Major arpeggio – E, G#, B, E), starting quietly and gradually becoming louder. This takes approximately 9 seconds.
Head turn	The robot slowly turns its head to the left, then to the right, then looks up, then looks down. This takes approximately 12 seconds.
Hand opening	The robot opens and closes both of its hands twice. This takes approximately 4 seconds.
Musical sequence 2 with hand movement	The robot plays a second short musical sequence (based on the Westminster Quarters). Whilst the music is playing, the robot slowly raises its arms to its face and rotates its wrists as if rubbing its eyes to wake up. The robot then returns its arms to their initial position and the music stops. This takes approximately 14 seconds.
Introduction	The robot raises its right arm, waves, and says, "Hello. My name is Russell. It's nice to meet you." It then lowers its arm again. This takes approximately 7 seconds.
Consent to proceed	The researcher asks the child if Russell (the robot) can stand up and waits for the child to agree before tapping the robot's head sensor to trigger the next movement.
Stand up	The researcher presses the sensor on the top of the NAO's head. The robot then says, "I'm going to stand up now – okay?" and stands up. This takes approximately 6 seconds.

Song and Dance

The second portion of the Capability Demonstration showed the robot's full-body

movements and more advanced musical and speech capabilities. The robot then performed

either "The Wheels on the Bus" (32 s), "The Itsy Bitsy Spider" (30 s), or a stereotypical Robot

Dance accompanied by upbeat electronic music (37 s).

The researcher says, "Russell has a little dance he's been working on, and he's really

excited to show you. You might know the song, so you can dance along if you want to. Can

he show you what he's been practising?" After getting the child's permission to continue, the

researcher presses the sensor on the robot's head to trigger the Song and Dance.

Stimulus and Response

Option 1: Question and Answer Session

In this option, the robot asked the child a series of questions. For each question, after

the child answered, the robot provided its own answer before asking the next question.

The researcher says, "Now Russell has a few questions he'd like to ask you to get to

know you better. He's really excited to find out about your favourite things. Is that okay?"

When the child indicates they are ready to start, the researcher touches the sensor on the

top of the robot's head to begin the activity. The robot asks the following questions, pauses

for the child to answer after each one, and does not ask the next question until the

researcher on the other side of the one-way mirror prompts it to:

> **Robot:** What's your favourite colour?
> **Child:** *[Responds.]*
>
> **Robot:** Cool! I like the colour blue. What is your favourite subject in school?
>
> **Child:** *[Responds.]*
>
> **Robot:** Interesting! I like reading. Do you have any brothers or sisters?
>
> **Child:** *[Responds.]*
>
> **Robot:** Neat! I have one brother and one sister. What is your favourite food?
>
> **Child:** *[Responds.]*
>
> **Robot:** Cool, I like to eat pancakes. How old are you?

Child: *[Responds.]*

Robot: Wow! I was built four years ago. What is your favourite animal?

Child: *[Responds.]*

Robot: Cool! My favourite animal is an elephant. What do you want to be when you grow up?

Child: *[Responds.]*

Robot: Awesome! I want to be a scientist, like my friends. What's your favourite game to play?

Child: *[Responds.]*

Robot: Fun! I like playing checkers. Thank you for answering all of my questions.

The researcher was available to clarify the robot's questions, if required. Parents who selected this option during the Phase 1 interview could choose to have the robot skip over any questions they did not think would be appropriate for their child.

Option 2: Following Game

In this option, the robot asked the child to complete a series of simple tasks and praised the child after they successfully completed its request.

The researcher says, "Now we have a game the two of you can play. Russell will ask you to do some things for him, and all you have to do is follow along. I'll play along with you, too. Does that sound okay?" After the child indicates they are ready to begin, the researcher taps the sensor on the top of the robot's head to start the activity. The robot makes the following requests, and the researcher on the other side of the one-way mirror waits until the child successfully completes the request before triggering the robot to make the next one:

1. Can you clap your hands?

2. Good job! Can you stand up?

3. Awesome! Can you sit back down?

4. Fantastic! Can you pat your head?

5. Great! Can you touch your nose?

6. Hooray! Can you wave at me?

The robot then says, "Great job! Thanks for playing with me!"

The researcher also completed the simple tasks with the child, in case the child was unsure of the instruction. Parents who selected this option during the Phase 1 interview could choose to have the robot skip over any requests they did not think would be appropriate for their child.

Option 3: Mindful Breathing

This option had the robot lead the child through a mindful breathing exercise. The mindful breathing exercise was developed based on exercises that control the duration of the inhale and exhale, which have been shown to effectively regulate stress responses (Brown et al., 2013).The robot first said that they will take some deep breaths with the child by breathing in for four beats and then out for seven beats. Before the robot and child commenced the breathing exercise together, the robot demonstrated the technique by slowly lifting his arms in front of his chest and counting aloud to four while raising his head, then lowering his arms and counting aloud to seven while tilting his head back down. The robot said that the child could do the arm motions with him, if they wished. The robot and the child repeated this together three times at a speed of 75 beats per minute, lasting about 30 s. Then, the robot led the child in gentle stretches in which they slowly looked up and down, and then left and right. This lasted about 45 s. The researcher completed the activity simultaneously.

Static Exploration

The researcher first explained that the robot needed to rest and is going to take a nap. After getting the child's permission to continue, the researcher tapped the robot on the head. The robot then said that he was going to sleep, says goodnight, returns to his initial seated position, and his LED lights turn off. This turned the robot's power off, which meant it would not respond to touch or any other stimuli.

Option 1: Free Exploration

The researcher invited the child to touch the robot by saying, "Would you like to come a bit closer and touch him? He's turned off now, so he won't mind. You'll just have to be gentle with him." The duration of this segment was determined by the child.

Option 2: Guided Exploration

The researcher asked the child to help them give the robot a "check-up". The researcher explained that they would ask the child to touch a certain body part on the robot; they then demonstrated this process by gently touching the robot's knee. After confirming that the child understood, the researcher asked the child to touch the robot's hands, mouth, shoulders, forehead, and elbows in turn. The following script was used:

While he's asleep, can you help me give Russell a quick check-up? I think you'll be really good at it. You can help me by touching different parts of his body when I say their name. So if I ask you to touch his knees, you'll just touch them like this. [The researcher demonstrates.] Does that sound okay? It would really help me out.

Great. Can you touch his hands for me?

Good job. Now can you touch his mouth?

Wonderful. Can you touch his shoulders?

Great. Can you touch his forehead for me?

Brilliant. And last, can you touch his elbows for me?

Great job, thank you! Everything's working perfectly. You did great!

The researcher provided clarification if the child was ever unsure of where the body part was located on the robot.

References

Brown, R. P., Gerbarg, P. L., & Muench, F. (2013). Breathing practices for treatment of psychiatric and stress-related medical conditions. *The Psychiatric Clinics of North America*, *36*(1), 121–140. https://doi.org/10.1016/j.psc.2013.01.001