International Journal of Social Robotics
https://doi.org/10.1007/s12369-023-01015-y

REVIEW

A Systematic Review of Familiarisation Methods Used in Human–Robot Interactions for Autistic Participants

Christopher D. Wallbridge[1,2] · **Carly McGregor**[1,3] · **Natalia Drozdz**[1] · **Elisabeth von dem Hagen**[3] · **Catherine R. G. Jones**[1,3]

Accepted: 3 May 2023

Abstract

There is a growing need for standardised familiarisation techniques within the human–robot interaction (HRI) community. This is particularly the case when considering autistic participants, who may have difficulties with the novelty and sensory stimulation associated with meeting a robot. Familiarisation techniques should be considered critical to research, both from an ethical perspective and to achieve research best practice, and are also important in applied settings. In the absence of standardised familiarisation protocols, we conducted a systematic review in accordance with PRISMA guidelines to better understand the range of familiarisation methods used in studies of HRIs with autistic participants. We searched for papers from four different databases: PubMed, Scopus, Web of Science and Science Direct. We identified 387 articles that involved HRIs with autistic participants. The majority did not mention a familiarisation phase (n = 285). A further 52 mentioned including familiarisation but without any description. 50 studies described their familiarisation. Based on a synthesis of these papers, we identified six familiarisation techniques that are commonly used. Using co-production techniques with the autistic community and other participant groups, future studies should validate and critically evaluate the approaches identified in this review. In order to help facilitate improved reporting and critical evaluation of familiarisation approaches across studies we have setup a familiarisation repository.

Keywords Familiarisation · Rapport building · PRISMA · Systematic review · Human–robot interaction · Autism · Research methods

1 Introduction

One group of participants that are often used within human-robot interaction (HRI) research is autistic people. Autism is a neuro-developmental condition that is characterised by differences in social communication and the presence of restricted and repetitive behaviours, interests or activities [19]. The difficulties in social interaction that can be experienced by autistic people have led to interest in whether HRI may help support aspects of social communication [61]. However, autistic people may experience difficulties when introduced to a novel robot and an unfamiliar testing environment. For example, autistic people often struggle with new situations or changes to their routine [45], and may experience high levels of anxiety [1]. Further, the sensory sensitivities that are common in autism may mean that the

---

Elisabeth von dem Hagen and Catherine R. G. Jones are equal contributors

✉ Christopher D. Wallbridge
wallbridgec@cardiff.ac.uk

Carly McGregor
mcgregorc1@cardiff.ac.uk

Natalia Drozdz
drozdzna@cardiff.ac.uk

Elisabeth von dem Hagen
vondemhagene@cardiff.ac.uk

Catherine R. G. Jones
jonescr10@cardiff.ac.uk

[1] Centre for Artificial Intelligence, Robotics and Human Machine Systems (IROHMS), Cardiff University, Cardiff, Wales CF10 3AT, UK

[2] School of Computer Science and Informatics, Cardiff University, Cardiff, Wales CF10 3AT, UK

[3] School of Psychology, Cardiff University, Cardiff, Wales CF10 3AT, UK

sounds, lights, tactile experiences or other sensory qualities of the robot could be distracting or distressing [44]. HRI are thought to be facilitated by the anthropomorphic characteristics of social robots [23] but autistic people may be less sensitive to these characteristics, affecting their ability to engage and familiarise themselves with the robot.

One important way to support effective HRI research and its applications is by using a familiarisation phase to introduce participants to the robot. A familiarisation phase is a general term to describe a specific introductory session that enables the participant to become familiar with the robot in a positive and supportive way. Importantly, there are clear ethical motivators for using effective familiarisation techniques as they should reduce participant distress or discomfort. Poor familiarisation practices can also compromise research by leading to participant withdrawal (e.g. [6, 29, 58]). It is also unclear whether different familiarisation methods can influence experimental findings, perhaps due to eliciting differing degrees of rapport or familiarity for the participant. Until standardised familiarisation methods exist this potentially important effect on the data cannot be explored or controlled. More broadly, insight into successful familiarisation techniques is important for applied settings, such as educational or clinical environments, where humanoid robots are becoming increasingly popular [38].

Our objective was to conduct a systematic review of familiarisation techniques used in HRI studies that included autistic participants, in order to identify existing familiarisation approaches. To be inclusive of papers that explored the autistic phenotype more broadly, we also included papers that studied people without a diagnosis but with high levels of autistic traits.

The systematic review will be presented in Sect. 2. Based upon our synthesis of the existing literature, we identified six broad approaches for familiarising participants with robots and discuss these in Sect. 3.

2 Systematic Review

We followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [53] for performing our systematic review. The flow diagram can be seen in Fig. 1. Our goal was to conduct a systematic review of the familiarisation techniques used by researchers for introducing autistic people, or those without a diagnosis but with high levels of autistic traits, to robots. We wanted to identify the range of familiarisation techniques used and explore the extent to which techniques were successful.

2.1 Identification

Following PRISMA guidelines, an initial search on the 24th of June 2021 was performed with the use of PubMed, Scopus, Web of Science, and ScienceDirect. To search for related records in PubMed, Scopus, and Web of Science the following search terms were used: robot and autis*. For ScienceDirect, (“*” cannot be used) the keywords: robot & autism, or robot & autistic, were used to find a group of appropriate papers. We did not restrict our search based on year. An initial 4335 papers were identified. See Table 1 for details.

We used Rayyan AI [52] to identify duplicate records. 421 records were automatically identified as exact matches and removed. A further 1904 possible duplicates were identified and assessed manually, resulting in 970 further duplicate papers being removed. We used Rayyan throughout the review process.

2.2 Screening

An initial screening was performed based on titles and abstracts of the 2944 remaining papers. The following inclusion criteria were used for screening:

- Papers that included participants with a diagnosis of autism/with suspected autism/or with measured autistic traits, either all groups or some of them.
- Participants interacted with the robots.
- Papers in English.
- Both quantitative and qualitative papers were included.

The following exclusion criteria were applied:

- Papers that did not include participants with a diagnosis of autism/with suspected autism/or with measured autistic traits.
- Surveys, glossaries, indexes, book chapters, systematic and literature reviews.

Of the 2944 papers, 2839 of the papers could be successfully screened based on their title and abstract. Of these 2321 were excluded, with 518 to be assessed for eligibility. However, we were unable to classify 105 of the papers in this way e.g. the metadata retrieved did not include the abstract. These records were retrieved in full at this stage. This resulted in nine more papers being included and the other 96 being excluded. This led to a total of 2417 being excluded and 521 papers to be sought for retrieval. Upon completion of the initial screening by one reviewer, another reviewer conducted a blind review of 305 randomly selected papers from the original 2944. This resulted in a 92% agreement rate. Of the 25

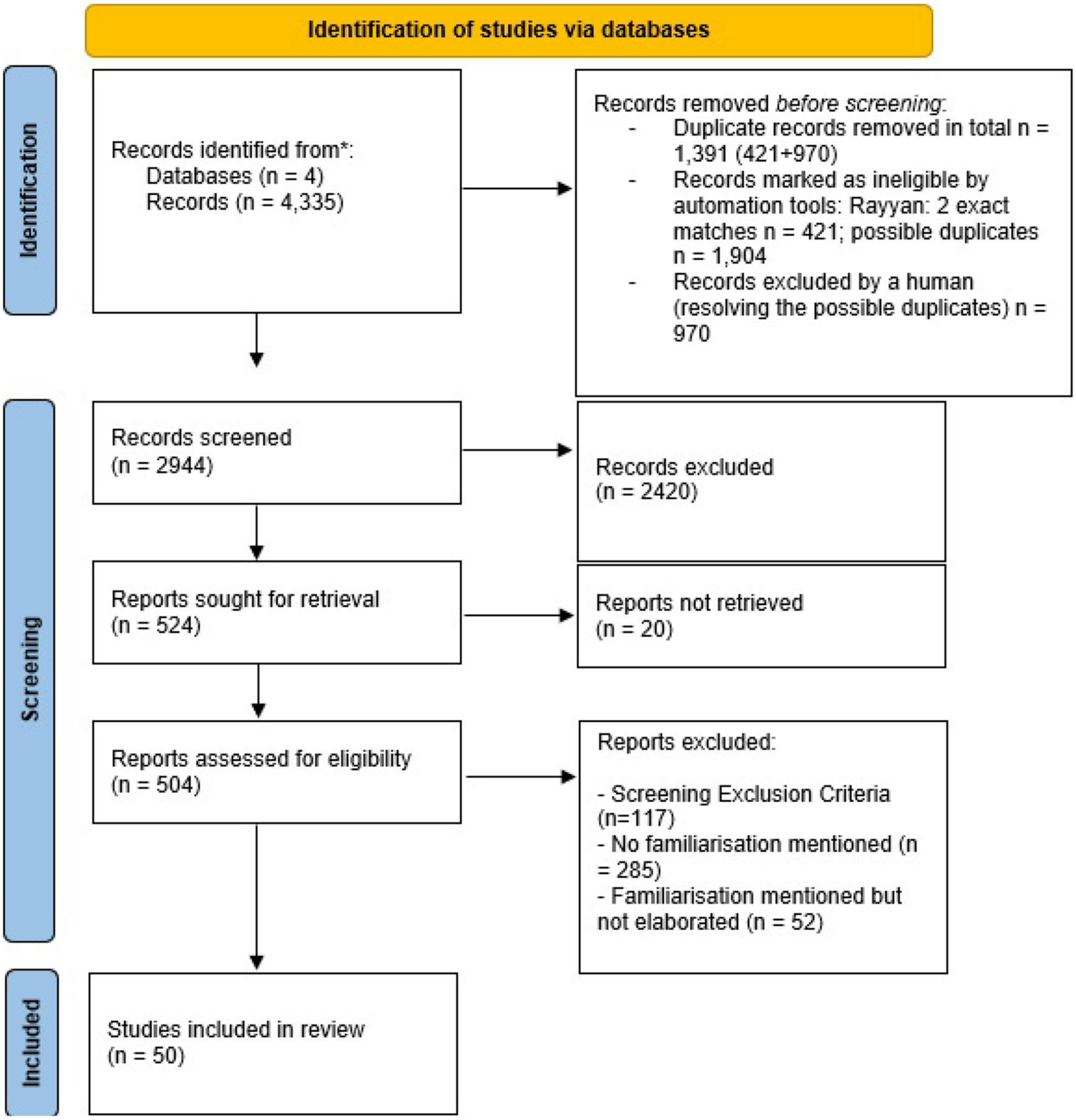

Fig. 1 The PRISMA flow diagram for the systematic review, showing the stages of identification, screening and inclusion

conflicts, all but five were resolved as per the original review. One more record was added to be sought for retrieval and four more records were excluded. This left a total of 2420 records excluded, and 524 papers being sought for retrieval.

Of the 524 papers that remained we were unable to access 20 papers. The remaining 504 papers were assessed for eligibility. Here, we first inspected the full paper to confirm that the original screening inclusion criteria had been met and there was no reason for exclusion. Applying these criteria, 117 papers were excluded. Many of these papers did not include interactions between the participants and robot, or the participants were typically developing. For reference, a list of the 387 papers that involved a robot interacting with autistic participants, those with suspected autism, or participants with measured autistic traits, can be found at https://github.com/CWallbridge/Familiarisation.

Table 1 Table showing the databases used, the search terms, and the number of records retrieved

Search engine	Search terms	Number of records
PubMed	Robot and autis*	227
Scopus	Robot and autis*	1118
Web of science	Robot and autis*	851
Science direct	'Robot' & 'autism'	1526
	'Robot' & 'autistic'	613

All records were retrieved on the 24th of June 2021

The initial screening of paper titles and abstracts only helped us select papers that included the right participants and a robot that interacted with participants. Surveying the full manuscripts was additionally necessary for us to categorise the included papers based on their description of familiarisation. Specifically, we could only include papers in the final review that provided adequate descriptions of familiarisation. The following additional inclusion criteria were therefore applied at this stage:

- A phase for familiarisation was described that included the robot. The word ’familiarisation’ did not have to be specifically used; other words used include:
    - Rapport Building
    - Habituation
    - Warm Up
- Papers that used a standardised familiarisation phase.

The following criteria were used for exclusion:

- Familiarisation was mentioned but no detail was given.
- Familiarisation was not mentioned at all. Note that a simple greeting was not considered familiarisation.

After one reviewer had classified these 387 papers, 285 papers were excluded as they did not mention any kind of familiarisation. A further 52 mentioned familiarisation, but did not provide any detail of their method and were also excluded. An independent review of a randomly-selected subset of 93 papers from the original 387 was conducted by another reviewer. Thirteen conflicts were found, of which 10 were resolved as per the original reviewer’s assessment, with three more papers added for final review. This left 50 papers for the final review. Table 2 shows a breakdown of the papers assessed by eligibility criteria. Notably, all of the 50 papers included participants with autism, with one paper including a participant with suspected autism and four giving no detail of diagnosis. None of the papers included participants with measured levels of autistic traits only.

Several of the excluded studies included multiple interaction sessions between the participant and the robot. For instance, 20 of the 52 papers excluded due to lack of detail of the familiarisation phase had multiple interaction sessions between the participant and the robot. It’s possible that some of these studies may have considered initial interactions between the participant and the robot as serving the purpose of familiarising the participant with the robot. However, in the absence of further detail, and in line with our exclusion criteria, these papers were not included.

Of the 50 papers that were included in the final review (see Table 3 for a summary), only one paper provided extensive details of the familiarisation phase [8] and one paper had as its goal the familiarisation of the participant with the robot [29].

Table 2 Table showing the breakdown of reports assessed for eligibility based on mention of familiarity

No familiarisation	Mentioned but not elaborated	Included
285	52	50

2.3 Review of Described Familiarisation Techniques

Below we describe the different familiarisation approaches reported in the literature. Although there were a variety of approaches used, it was possible to group these into six broad familiarisation methods.

2.3.1 Capability Demonstration

One common familiarisation approach was to show the participant the capabilities of the robot e.g. [2, 16, 18, 20, 24–29, 57, 62–64, 66, 68, 69, 72]. This was often done in ways to engage participants’ interest e.g. by making the robot sing and dance, and was often framed as an introduction to the robot. While this is potentially an effective way to ensure there are no unfamiliar robot movements during the study or session with a practitioner, care must still be taken with how the capabilities are introduced. For instance, it has been reported that even initial movement of the robot can startle the participant sufficiently to elicit their withdrawal [51].

In Petric et al. [55], the authors found that an initial pilot with seven typically developing children was unsuccessful due to significant levels of wariness towards the robot, including one child leaving the room. In order to improve participant engagement, a key change that the authors made was to expand their familiarisation phase. Their final familiarisation protocol involved the robot using its singing and dancing capabilities to make up to three appealing invitations for the child to approach them. The next phase of the study started once the child had engaged their attention with the robot. The amount of singing and dancing increased on each invitation. Of 19 participants in the final study, two participants were withdrawn due to anxiety and requests to leave the room. It was not specified in the paper at what stage these two children were withdrawn. However, the reported data suggested that all participants who completed the study responded within the three bids for attention. The evidence in this study suggests a robust familiarisation phase may reduce participant withdrawal.

Huskens et al. [30] integrated a demonstration of the robot into a story about the robot that was designed to engage participants. The robot introduced itself, but it had no name and appeared to be sad about this to evoke a sympathetic

Table 3 The summary of the included studies in the systematic review

Citation	Age of participants (years)	Diagnosis	Robot	Categorised familiarisation type
[2]	6–7	ASD	NAO	Capability demonstration
[3]	9	ASD via DSM 5	ARC	Initial experimental session
[4]	Child—age not specified	No detail	NAO	Static exploration, stimulus and response
[7]	7–11	ASD	KiliRo	Static exploration
[8]	3–6	ASD w/ speech impairment or language delay	CHARLIE	Static exploration, remote control
[10]	5–16	ASD	TeoG	Static exploration, free play
[11]	4–6	ASD via DSM-IV	NAO	Free play: elements of capability demonstration & stimulus and response
[12]	Child—age not specified	ASD	PLEO	Free play
[16]	17–19	ASD	LEGO MindStorms NTX	Initial experimental session, capability demonstration
[18]	5	ASD	NAO & MiRo	Capability demonstration
[20]	5–11	ASD via ADOS	Gipy	Capability demonstration
[21]	7–12	ASD, no ID	Daisy robot	Capability demonstration, stimulus and response, element of static exploration
[24]	6–7	ASD via DSM-IV	Pekoppa	Capability demonstration
[25]	6–7	ASD via DSM-IV	Pekoppa	Capability demonstration
[26]	7–11	ASD via DSM-V	Pekoppa	Capability demonstration
[27]	2–5	No detail	QueBall	Capability demonstration, stimulus and response
[28]	7–11	ASD	MARIA	Capability demonstration
[29]	8–12	ASD, severe to mild ID	KASPAR	Capability demonstration, stimulus and response
[30]	8–12	ASD via DSM-IV, no ID	NAO	Capability demonstration
[31]	Child - Age not specified	No detail	NAO	Static exploration, capability demonstration

Table 3 continued

Citation	Age of participants (years)	Diagnosis	Robot	Categorised familiarisation type
[33]	2–6	PDD-NOS or Autism	iRobi	Static exploration
[34]	4–5	ASD, low to high functioning	CuDDler	Initial experimental session
[35]	7–11	ASD via DSM-IV, low to high functioning	KASPAR	Static exploration
[36]	5	ASD via DSM-V	NAO	Stimulus and response
[37]	5–10	ASD, severe ID	White, spherical prototype	Static exploration
[40]	18–27	ASD via DSM-V, DISCO	Actroid-F	Remote control
[49]	4–5	ASD via DSM-V	NAO	Initial experimental session
[50]	7–9	ASD	NAO	Stimulus and response
[51]	6–9	ASD	NAO	Stimulus and response
[55]	1–5	ASD	NAO	Capability demonstration
[56]	7–9	ASD, low severity	Daisy robot	Initial experimental session
[57]	4–9	ASD via ADOS & DSM-IV	Probo	Stimulus and response, capability demonstration
[59]	7–11	ASD	NAO	Initial experimental session
[62]	5–10	ASD, verbal and non-verbal children	Robota	Capability demonstration
[63]	5	ASD	Robota	Capability demonstration, initial experimental session
[64]	5–10	ASD, verbal and non-verbal children	Robota	Capability demonstration
[65]	Child—Age not specified	ASD	Robota	Initial experimental session
[66]	5–10	ASD, verbal and non-verbal children	Robota	Capability demonstration
[67]	Child—age not specified	No detail	KASPAR	Free play
[68]	6–8	ASD via CARS, ADOS	NAO	Capability demonstration, static exploration
[69]	5–12	ASD via ICD-10, DSM-IV or DSM-V	Zeno/Milo	Capability demonstration
[71]	5–13	ASD via ADOS, moderate to borderline ID	NAO	Capability demonstration
[72]	5–9	ASD via ADOS/ADI	Humanoid robot, box robot	Capability demonstration

Table 3 continued

Citation	Age of participants (years)	Diagnosis	Robot	Categorised familiarisation type
[73]	5–7	ASD, no ID	Probo	Free play: elements of capability demonstration, stimulus and response & Static exploration
[75]	3–5	ASD via CARS	RoboParrot & Sphero	Stimulus and response
[76]	2–6	5 with ASD via DSM-IV, 1 suspected ASD	NAO	Stimulus and response
[77]	59–70	ASD w/ ID	Robot seal Paro	Static exploration
[80]	8–12	ASD, high functioning or Asperger's syndrome	2 robots A and B, make unknown	Static exploration
[81]	5–8	ASD via DSM-IV, ADOS/ADI/SRS	NAO	Stimulus and response
[82]	5–8	ASD via DSM-IV & ADOS/ADI	NAO	Stimulus and response

DSM diagnostic and statistical manual of mental disorders [14], *ID* intellectual disability, *ADOS* autism diagnostic observation schedule [46], *PDD-NOS* pervasive developmental disorder - not otherwise specified, *DISCO* diagnostic interview for social and communication disorders [43, 79], *CARS* childhood autism rating scale [70], *ICD-10* international classification of diseases (World Health Organisation), *ADI* autism diagnostic interview [47], *SRS* social responsiveness scale [13]

response. Participants and other children present were asked to name the robot in the first session. In a follow-up interaction, the robot thanked the participants and other children for giving it a name. Although it is unclear how the participants would have responded to the robot without the naming process, this is an example of how storytelling within familiarisation approaches could be used to potentially enhance rapport.

Fachantidis et al. [21] Ismail et al. [71] Shamsuddin et al. [31] described an introductory rapport session where the robot was initially static for 45 s. The robot would then move its head slowly and 'blink'. This may have had the benefit of slowly introducing a participant to the fact that the robot can move, reducing the possibility of the participant being startled or surprised.

2.3.2 Static Exploration

An additional familiarisation technique was to allow the participant to explore the form of the robot while it was in a passive state e.g. [8, 10, 21, 35]. Often this was achieved by enabling the participant to touch the robot, which was taken as an important indicator that the participant was happy interacting with the robot e.g. [68, 77].

Jeon et al. [33] investigated the use of humanoid robots in supporting an intervention to facilitate communication in non-verbal autistic children. During the baseline sessions, the child and therapist were seated at a table while the child engaged in simple activities with the therapist and their communication was measured. The robot was placed on the table in the same position that would be used for the subsequent intervention. It was therefore available to the child during the baseline sessions but did not initiate interaction. Only one of the four participants is reported to have approached the robot during the baseline sessions. Aryania et al. [3], Aziz et al. [4], Bharatharaj et al. [7], Ismail et al [31], Kostrubiec and Kruck [37], Yin and Tung [80] also used a period with a static robot to act as familiarisation for their participants.

2.3.3 Stimulus and Response

Aziz et al. [4], Fachantidis et al. [21], Malik et al. [50], Miskam et al. [51], Pop et al. [57], Soleiman et al. [75], Tapus et al. [76], Zhang et al. [81, 82] all included question and answer sessions with the robot. Participants were encouraged to ask the robot simple questions such as, "What is your name?" to promote two-way interaction. The robot could also display responses to other stimuli, such as waving in response to the participant waving. A more tailored approach was also observed, with Korneder et al. [36] using three requests that were known to be part of the participants' repertoire of abilities, and likely to be responded to by the participant e.g. ’Clap your hands’. Golliot et al. [27] enabled the participant to play with the robot using a stimulus and response format that was less demanding than some of the other approaches. The robot changed colours, played sound or did both when the participant touched it.

Huijnen et al. [29] was the only paper we reviewed where familiarisation was the primary aim of the study. This study was a pilot study specifically focused on enabling autistic children between the ages of 6 and 12 years to ‘make contact’ or familiarise themselves with the robot KASPAR. Objective measures of children ‘making contact’ were obtained for KASPAR, and compared with those obtained for a human teacher. Pre-determined dialogue could be triggered in KASPAR based on a child’s actions. KASPAR would attempt to make contact by greeting the child and introducing itself, asking questions, using gestures such as waving and playing games. KASPAR would also respond to touch sensors being triggered. The session lasted for approximately 10 min. Children showed increased contact attempts with KASPAR, relative to the teacher, across four areas -non-verbal imitation, touching, length of attention, amount of distraction. This was compared to only one measure, positive verbal utterances, in which the teacher elicited a higher contact ‘score’. The authors [29] described that KASPAR spoke more slowly than the teacher and noted that this could have been a beneficial characteristic as it gave children more time to respond and promoted calmness.

2.3.4 Initial Experimental Session

Using a different approach, three studies used a familiarisation phase that was identical to the experimental phase [3, 56]. Robins et al. [65] described using an initial session with the only variation being that this familiarisation session was one-to-one, rather than in pairs, as in the main study. For two studies that used multiple interaction sessions, the lack of an explicit familiarisation phase was reported to have a negligible impact on the results over the course of repeated sessions [63, 64]. In some cases, the initial experimental session was expanded to include specific training of the participant with the robot e.g. [34] where the participants were told that different screens corresponded to different mouse buttons, and that they should follow the movement of the robot’s head.

While not intended as part of their study design, Louie et al. [49] found it necessary to have the therapist also provide the same prompts as the robot for several of their interventions in two of their three participants. They based this approach on techniques used to help familiarise autistic children with a new therapist. In this study, the last-minute change altered the experimental design and was applied inconsistently across participants, highlighting the importance of planning familiarisation in advance. Similarly Qidwai et al. [59] acknowledged that their initial experimental session was not consistent with the rest of the data, and had to be considered part of familiarising the child with the robot. Costa and colleagues collected data for two studies sequentially. They used one of the studies (Costa et al. [15]) to provide an introduction to the robot for when it was used in the second study (Costa et al. [16]).

2.3.5 Remote Control

An additional type of familiarisation that was observed across the studies was the use of remote control or teleoperation of the robot. Boccanfuso et al. [8] provided an extensive description of their study protocol, including details of their two familiarisation phases where they described the behaviour of the robot and criteria for moving from one familiarisation phase to the next. In both familiarisation phases, the child was encouraged to make eye contact with both the researchers and the robot. In the first phase the robot was set to a static mode, and the child was given an opportunity to physically explore the robot (i.e. ‘static exploration’ familiarisation). This phase was considered a success when the child had been observed to approach the robot, touch the robot and then move the robot’s arms. In the second phase, the child was given the opportunity, guided by the researcher, or parents if necessary, to control the robot remotely. To complete this phase, the child had to lead the robot through an activity at least once, and move the robot themselves using the remote control. Other studies also gave participants the opportunity to remote control a robot themselves before the main interaction [10, 40].

2.3.6 Free Play

Finally, free play familiarisations were often mentioned [10–12, 67, 73]. It was also a commonly used description in studies that were excluded from this systematic review due to lack of detail. Even in studies that met inclusion criteria for this review, full details of the free play session were often not provided [12, 67, 73]. Where details were provided, they often fell within one or more of the above-described approaches. For example, Brivio et al. [10] described a period of static exploration, followed by allowing the children to play with the robot. This free play had instances of stimulus and response, dancing and even remote control. Similarly, Cao et al. [11] had a free play interaction that consisted of a capability demonstration by dancing and talking and, stimulus and response.

Robins et al. [67] found that some participants choose to touch the robot during free play, whereas others would opt to ask questions. This highlights that free play elicits a range of different activities across users.

Table 4 Table showing the summary of withdrawal data from the reviewed papers

Citation	No. participants	No. withdrawals	Familiarisation category	Withdrawal reasons
[3]	5	3	Initial experimental session	Unwillingness
[11]	30 (15 with ASD)	8 (3 with ASD)	Free play: elements of capability demonstration & Stimulus and response	Reluctance & technical difficulties
[18]	5	1	Capability demonstration	Nervous with robot
[29]	11	2	Capability demonstration, stimulus and response	One upon seeing the robot, one because they wanted to be shown the robot beforehand
[55]	26 (7 with ASD, 7 Pilot (0 with ASD))	7 (5 Pilot, 0 with ASD)	Capability Demonstration	Anxiety/wariness of the robot
[72]	10	4	Capability demonstration	Aversive reaction e.g. distress or not wanting to interact with robot
[73]	32	2	Free play: elements of capability demonstration, stimulus and response & static exploration	One due to a medical reason, one did not complete robot condition

Participants all have ASD unless otherwise specified

2.4 Withdrawals

As well as the familiarisation methods used, we also looked at the withdrawals reported from the included studies. Only 7 of the 50 included papers reported any withdrawals. It is unclear if this is because the other studies did not have any withdrawals or if this data was not reported. A summary of reported withdrawal data can be seen in Table 4.

Petric et al. [55] initially had a very high withdrawal rate during their pilot study (5 out of 7 participants). By extending their familiarisation protocol and making some adjustments, the rate of withdrawal dropped to just 2 of 19 participants in their main study. All the withdrawals were considered due to anxiety or wariness around the robot. Di Nuovo et al [18], Huijnen et al. [29], Short et al. [72] also reported withdrawals due to nervousness around the robot (1 of 5, 2 of 11 and 4 of 10, respectively). All four used a capability demonstration as part of their familiarisation, although Huijnen et al. [29] additionally included stimulus and response. Cao et al. [11] used a free play that included elements of capability demonstration and stimulus and response. However, the reasons for withdrawal (8 out of 30) are less clear for this study. The authors stated reluctance, and technical difficulties, but do not give a breakdown of how many were caused by each.

While the reasons for reluctance in Aryania et al. [3] were not clear, the withdrawal rate was high (3 out of 5). This was the only study that had withdrawal data reported that used an ‘initial experimental session’ for familiarisation. In contrast the study by Simut et al. [73] had a very low withdrawal rate (2 of 32, one of which was due to a medical condition). This study used a free play style familiarisation with elements of capability demonstration, stimulus and response, and static exploration.

3 Discussion

We systematically investigated the familiarisation techniques used to introduce autistic participants to humanoid robots across a range of studies and interventions. Our assessment of 50 studies that reported familiarisation techniques identified six types of approach: Capability demonstration, static exploration, stimulus and response, initial experimental session, remote control and free play. However, we generally found that very little detail was reported about the familiarisation techniques used. Of note, 74% of the eligible studies that we reviewed did not provide any details about familiarisation, making it unclear whether any was used. We argue that it is important to document familiarisation as part of good research practice. Familiarisation is likely to improve data quality and reduce participant withdrawal. Further, better reporting of familiarisation methods provides a means for more rigorous replication. Importantly, it also supports a more comfortable and positive experience for participants, whether taking part in research or working with robots in educational, clinical or community contexts.

One point of difference across studies was deciding when to terminate familiarisation sessions. This was sometimes left to the judgement of the experimenter, sometimes to someone who knew the participant well, and on other occasions by using a fixed duration. These judgements were subjective, with this variance likely to be increased if decisions were being made by different people (e.g. parents or caregivers vs. experimenter). Even in the case of fixed durations, it was not reported why a specific timescale was selected.

Across the studies, there was limited evidence of information being gathered about participants before meeting the robot so that the familiarisation process could be supported by knowledge of the participant. Korneder et al. [36] used requests that had been established as part of a participant's repertoire, making participants more likely to respond positively to these requests. This suggests that the use of a 'pre-familiarisation' phase could be helpful as it could help the experimenter or practitioner tailor the experience to participants likes, dislikes and capabilities, as well as enable the exchange of any other relevant information such as the way that the participant might indicate they are distressed. This process could also inform the selection or modification of familiarisation processes. Tailoring studies to participant needs and abilities is also in line with best practice for research involving the autistic community [41]. One of Huijnen et al. [29] participants requested to see the robot before they would agree to take part, and reluctance to attend the study has also been reported in Cao et al. [11]. These examples highlight how pre-familiarisation could also include directly preparing the participant for the study visit. For example, participants could be sent a storyboard explaining the plan for the study and a picture of the robot. Other suggestions include showing the child a short video of the robot and testing environment, or even a pre-visit [41].

With only seven studies reporting withdrawal information, we are not able to draw any firm conclusions on which methods are most effective. A tentative interpretation of the data would suggest that using an initial experimental session on its own was the least effective method of familiarisation, with a 60% withdrawal rate reported in Aryania et al. [3]. Three of the studies using capability demonstration reported withdrawal rates between 10 and 20% [18, 29, 55], which would suggest it is reasonably effective. However, Short et al. [72], who also used capability demonstration, had a 40% withdrawal rate. It is unclear why this would be the case, although a possible explanation is that they used a custom robot. In contrast, the other three use more established robots (NAO, Miro and KASPAR) that were designed to work well with children. This may suggest that certain robots may need more extensive familiarisation than others. Although the free play familiarisation -with elements of capability demonstration and stimulus and response- by Cao et al. [11] was associated with a relatively high withdrawal rate of 27%, Simut et al. [73] also used a free play familiarisation and had only one participant drop out, making it the most successful study for participant inclusion. Details on what the robot did were sparse, but it did contain elements of capability demonstration, stimulus and response and static exploration.

Based on a synthesis of the six familiarisation techniques discussed in Sect. 2.3, in the following section we discuss each familiarisation approach, suggest potential advantages of their use, and provide guidance on reporting familiarisation to improve consistency and enable best practice. However, with limited information provided within the studies we reviewed, our suggestions are preliminary and will require empirical investigation. Due to the wide variety of robots, experimental designs and types of participants, the familiarisation approaches could be used flexibly, allowing researchers to tailor their familiarisation for the purposes of their study, using as many or as few methods as needed. The six methods are summarised in Table 5.

3.1 Identified Familiarisation Approaches

While the approaches identified in this review are informed by familiarisation methods previously reported in HRI with autistic participants, none of the suggested methods are necessarily specific to this group of participants. Selection of the methods used should be based both on the needs of participants and the design of the study, and adaptations to the proposed methods are possible to accommodate different populations. For example, a study whose participants span a wide range of ages may need different versions of the stimulus and response familiarisation for a 5-year-old compared to a 13-year-old. Similarly, the stimulus and response method may not be suitable if the premise of the study is that the participant has had minimal back-and-forth interaction with the robot. Most of the studies we reviewed used one or two familiarisation methods, and further research is needed to determine the optimal amount of familiarisation that is necessary. Researchers may wish to use them in increasing order of complexity if choosing to use multiple familiarisation methods. The identified familiarisation methods should be equally applicable to studies involving typically developing participants, although further investigation is needed. It is worth noting, however, that the methods proposed here are based primarily on research involving HRI with children –only two studies reviewed here had adult participants [40, 77]– and the methods may therefore not be as suitable for interactions with adults.

3.1.1 Capability Demonstration

The work found in [2, 18, 20, 24–27, 29, 57, 62–64, 66, 68, 69, 72] suggested that a familiarisation phase demonstrating relevant capabilities or functions of the robot could be a useful way of introducing participants to the robot. A comprehensive interpretation of the capability demonstration would be to demonstrate all robot functions that are relevant to the

Table 5 Table showing a summary of the identified familiarisation techniques

Method	Description	Potential advantages
Capability demonstration	This phase is a demonstration of all the capabilities of the robot that will be used in the study	Does not require an interactive element. Useable with a group of participants. Allows grouping of children for later activities
Static exploration	The participant is shown the robot, who is static and in a safe position, and given the opportunity to touch and feel the robot	Minimal programming requirement. No demand for interaction. Touch may facilitate rapport
Stimulus and response	The participant and robot take turns eliciting a response from each other e.g. question and answer	Participant learns how to communicate with the robot. Allows experimenter to assess communication. May enable participant to feel in control
Initial experimental session	One or more initial sessions of the study protocol are used. These sessions may be supported by an experimenter or therapist to ensure the participant can engage with the eventual experiment or intervention	Minimal additional development required. Participant can become familiar with the experimental paradigm. Adapatations such as scaffolding the participant's responses are possible
Remote Control	Participant is given an opportunity to remote control the robot. The participant can explore all the capabilities of the robot relevant to the study	Makes salient the robot can be human controlled. May enable participant to feel in control
Free Play	The participant freely chooses the way they interact with the robot. A broad or narrow range of interaction methods can be made available	Gives participants choice. Could integrate other familiarisation techniques in a naturalistic way

participant's session. For example, if the robot speaks during the experiment then the robot should be shown speaking, and similarly if the robot moves its limbs during the experiment then this should also be demonstrated. To enhance the acceptability of these demonstrations to the participant, and based on Fachantidis et al. [21], Ismail et al [31], Shamsuddin et al [71], initial actions should be slow and quiet, for example, with a narrative that the robot is waking up or as an 'introduction' to the robot. More energetic actions, such as performing a dance, could occur later in this phase. This approach of beginning with quiet sounds aligns with difficulties autistic people can have with loud noises [42]. However, autistic hypersensitivity to sounds can mean that noises that do not bother most people, based on either intensity or sound type, can be distracting or distressing [42]. Therefore, it cannot be assumed that it is sufficient to rely on starting with a low volume.

Importantly, the capability demonstration is about showing the participant the robot and does not necessarily include an explicit interactive element. Some studies did include an interactive element. For example, inviting the invite participants to complete actions alongside the robot (e.g. [55]) or perform an activity together with the robot (e.g [30]). However, we found that other methods, particularly stimulus and response, involved active engagement from the participant and it could be useful for researchers to draw upon distinct passive and active familiarisation techniques. The potential passivity of the capability demonstration means it could be used with a group of participants e.g. [30]. For example, a group of school children could be introduced to the robot in a classroom setting prior to being tested separately. This also affords the opportunity to pair or group children, where confident children may support less confident children [39].

To enhance consistency of reporting of this phase, researchers could describe the capabilities displayed, the duration of this phase, group size (if applicable), and any interactions that took place with the participants. A potential feature of the capability demonstration method is that its completion can be objectively determined by the robot displaying all the functions that are relevant to the participant's session.

3.1.2 Static Exploration

A form of static exploration was documented in a range of different studies [7, 8, 10, 21, 31, 33, 37, 71] in the current review. This method provided participants with the opportunity to become familiar with the robot by touching it while it was typically in an unresponsive mode. Importantly, we would suggest that the robot should be in a static and safe position, such that touching the robot would not cause it to fall over. Participants were typically invited to touch the robot, or sometimes explicitly asked to touch the robot [77].

Practically, static exploration could be advantageous as it involves minimal programming. Another reason for favouring this approach is that touch may be important for building stronger human-robot relationships [79] and this phase enables 'safe' tactile interaction. The approach is safe because the robot will not move but also safe as the participant can explore the robot without the demands of interaction. This approach may be beneficial for participants with high levels of anxiety. Particularly, static exploration could support participants with high levels of intolerance of uncertainty, a strong correlate of anxiety in autistic populations [32], as they can be reassured that the robot will not do or say anything. From an experimental perspective, the technique would also be useful if the experimental protocol requires no previous social interaction with the robot.

Completion of this phase could be based on a fixed duration of participant exploration, or the participant stating that they are finished. When reporting its use, researchers could also highlight whether they used active encouragement to get participants to touch the robot, as well as the static position used by the robot.

3.1.3 Stimulus and Response

This method, where participant and robot interact together, is based on familiarisations used across a variety of studies [4, 21, 27, 36, 50, 51, 57, 76, 81, 82]. Typically, participants and the robot took turns eliciting responses from each other. These were through a variety of modalities available to the robot. For example, in one study the robot responded to touch sensor triggers e.g. [27], whilst in another they engaged in verbal questions and answers e.g. [36]. When using this approach, preferences and abilities of the participants could inform the type of stimulus and response familiarisation that is used.

Using this technique, the participant could learn both how the robot communicates with them and how they can communicate successfully with the robot. This might be particularly important if the experimental study requires the robot to understand the participant's speech as it could enable speech intelligibility to be informally assessed. Robots and other electronic devices can have difficulty understanding the speech of autistic children [60] and those with learning disabilities [74], meaning this could be an important part of the protocol.

Central to the stimulus and response method is the contingency between participant and robot. Autistic people can have difficulty with predicting stimuli [17, 54], alongside an intolerance of uncertainty in everyday life [9]. Therefore, the sense of control engendered by the stimulus and response method may be a mechanism through which participant comfort with the robot can be achieved.

When reporting this type of familiarisation, and to ensure replicability, researchers could report the stimulus–response options used, the number of turns between the participant and the robot, and the duration of the phase.

3.1.4 Initial Experimental Session

Using this method, an initial experimental session of the study protocol, as reported in the methods section of the paper, was used to introduce participants to the robot and experiment [3, 34, 49, 56, 59, 62–64]. In previous studies, participant performance in the initial experimental session did not affect the overall results, and were therefore kept in the analysis [63, 64]. However, the initial experimental session could also be considered a practice trial and discarded from later analysis.

This method could be an effective technique if it is advantageous for the participant to be familiar with the study paradigm or intervention before it begins. In addition, it allows for an adapted, or scaffolded, initial experimental session where the therapist or experimenter could support the child to initially interact with the robot [49]. However, it should also be considered that the initial experimental session will not have been designed specifically to familiarise participants and so may not be optimised for a smooth introduction. It may therefore be useful to consider this approach in combination with other familiarisation techniques.

To support consistent reporting, researchers could report on the number of initial or practice sessions used. They could also report on any key differences from the experimental tasks or trials, such as additional support provided.

3.1.5 Remote Control

The remote control method provided participants with the ability to remote control the robot, and was used in a small number of studies [8, 10, 40]. The technical challenges of this approach, along with the limitations of some robots, may explain why this method was not often used to familiarise participants. The remote control interface could be the same interface that the experimenter uses to control the robot, or a simplified interface that easily enables the participant to explore the capabilities of the robot.

A key feature of this method is that it makes salient that the robot is controlled by a human. This type of demystification may be appropriate for certain studies or activities e.g. classroom STEM activities such as learning to programme a robot. The approach would also work well as a practice, similar to an initial experimental session, if this was required during an experimental phase of a study. It may also be an advantageous technique for participants who are particularly intolerant of uncertainty as this type of familiarisation makes salient that the robot can be controlled. However, the method would not be appropriate familiarisation phase for researchers or practitioners interested in the robot behaving as a proxy human.

In reporting its use, researchers could report details of the interface given to participants, and the duration of the remote control sessions.

3.1.6 Free Play

Free play, as reported in [10, 11, 67], often included a combination of the familiarisation approaches described above. Importantly, free play provided participants with the choice of how to interact with the robot. Although we use the term free 'play', the activity would be suitable for older participants but the term play could be replaced by 'engagement' to be more age appropriate. Perhaps reflecting a preference for being in control, autistic people tend to show enhanced engagement when they have a choice [48, 78]. Therefore, although further research is required, free play could be a motivating familiarisation phase.

Free play is also a flexible option, which can enable other types of familiarisation to be executed in a more free-flowing manner than would typically be used. For example, the robot could be programmed to ask questions and respond to a participant, similar to the stimulus and response method, but whether this happens and the extent to which this happens could be determined by the participant. However, a key consideration is that free play is less well controlled than other techniques because it is driven by the participant's choices. This may introduce unwanted variability into the familiarisation process. Given this, future research could explore the effectiveness of a hybrid familiarisation in which participant choice is added into one of the more structured familiarisation methods. For example, asking a child to select what song they want the robot to sing in a capability demonstration session.

Another consideration is that free play may feel overwhelming for a participant who is unfamiliar with the robot. The free play activity may need scaffolding by having the experimenter, teacher or therapist play with the participant, which could be used as an opportunity to build rapport with the participant as long as the participant was driving the choice of activity.

In reporting free play, researchers could highlight the activities the participants engaged in, and the duration of the session.

3.2 Limitations

We have synthesised familiarisation methods across the papers reviewed. However, much of the familiarisation information provided was sparse, which has limited our conclusions. Of the papers we included, only two provided enough detail for replication [8, 29].

We were also unable to extract detailed information on the effectiveness of the different familiarisation methods. None of the papers presented analysis of their familiarisation method. Only a few studies provided detail on withdrawal data (see Sect. 2.4). Only one study [55] provided a direct comparison of the effects that a familiarisation phase can have, although the comparison was with a teacher rather than the effect of meeting a robot under different conditions of familiarisation.

The limited details provided about familiarisation methods also meant it was difficult to compare across studies. With better reporting of familiarisation, in the future we may be able to provide more informed cross-study comparisons. Future work could also establish relevant baseline measures, such as subjectively reported or objectively observed/measured levels of comfort, that can be used across studies to support the development of effective familiarisation techniques.

None of the studies provided any details as to why they chose their familiarisation methods. As such we are limited in what we have learnt about how to choose appropriate methods. We were also limited on what we can recommend about applicability of the familiarisation methods to different robots and contexts. For instance, different types of robots may lend themselves more to one type of familiarisation than another, or different participants may respond differently to different techniques. However, it is clear that the specific needs of the participants and the requirements of the study are both important considerations in selecting familiarisation approaches. Better reporting and better methodological justification are both key to enabling more sophisticated critical evaluation of different familiarisation techniques in the future.

4 Future Work

Adopting consistent approaches to familiarisation and the reporting of familiarisation should improve replicability and consistency across studies, and allow researchers to concisely provide full details of their approach to familiarisation. The familiarisation methods proposed here are based on a synthesis of existing research that has been identified via systematic review. However, future work is needed to directly evaluate the effectiveness of the different familiarisation methods to enhance HRI studies, particularly those with autistic participants. Following the collection of appropriate data, it may be possible to create a best-practice standardised protocol for familiarisation, much like the standard practices used in other aspects of robotics research e.g. the godspeed questionnaire for data on participant opinions of a robot [5].

In the future. research evaluating familiarisation methods across the following areas would be particularly beneficial:

1. Ensuring the comfort of participants, both from a position of ethical responsibility and in order to minimise withdrawal.
2. Increasing the validity of data collected, e.g. by removing variability induced by participant anxiety about the robot.
3. Identifying salient indicators that a participant is comfortable with the robot, and specific recommendations for how long familiarisation should last.
4. Identifying the applicability of different methods for different robots and participants

In alignment with calls for more co-production of research [22], future investigation of the efficacy of these methods should include meaningful input from the autistic community. This is particularly relevant for robot familiarisation, which is specifically intended to make HRI a more comfortable experience for autistic people and should directly reflect their needs and preferences.

4.1 Repository

To assist in the development of familiarisation best-practice, we have created a freely-available repository where researchers can add details of their familiarisation methods and relevant code: https://github.com/CWallbridge/Familiarisation. There is also scope within the repository to extend the level of detail provided for each method, to include example scripts/code as appropriate, and to report on the effectiveness of the familiarisation method. Using such a repository would provide the ability to use and reference very specific incarnations of the methods. These scripts may be specific to a specific make and model of robot, and could provide the exact actions or words for the experimenter to ensure the familiarisation techniques could be directly replicated. By also ensuring that contributions to this repository are reporting enough detail, we can make comparison across studies to help with the above research goals. An up-to-date guide on submitting to the repository can be found on the site's readme.

5 Conclusion

Based on a systematic review of familiarisation approaches in HRI with autistic participants, we identified six familiarisation approaches. The familiarisation approaches identified here may be useful in a wide variety of contexts where autistic people are engaged in HRI, including research, educational, clinical and community settings. However, with limited data on effectiveness, these familiarisation approaches require empirical investigation to develop and refine the methods.

Given the lack of familiarisation reporting in the literature, we have created a repository where authors can upload their familiarisation techniques, and report on details of effectiveness. We hope that this improved reporting will assist all those investigating HRI, especially with autistic participants, to effectively create and/or choose familiarisation techniques.

Acknowledgements This work was conducted with support of the Centre for Artificial Intelligence, Robotics and Human–Machine Systems (IROHMS) operation C82092 and partially funded by the European Regional Development Fund (ERDF) through the Welsh Government.

Data Availibility The list of papers that were included after screening –involving participants either diagnosed with autism, or having autistic traits, that have interacted with a robot– can be found at https://github.com/CWallbridge/HaRMoNI. All papers included in the review stage have been cited and a summary can be found in table 3.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethics At all stages the authors have ensured the integrity, quality and impartiality of this research, and where appropriate funding has been acknowledged. This research has not directly involved participants.

References

1. Accardo AL, Pontes NM, Pontes MC (2022) Heightened anxiety and depression among autistic adolescents with adhd: findings from the national survey of children's health 2016–2019. J Autism Dev Disorders pp 1–14
2. Arent K, Kruk-Lasocka J, Niemiec T, et al (2019) Social robot in diagnosis of autism among preschool children. In: 2019 24th international conference on methods and models in automation and robotics (MMAR). IEEE, pp 652–656
3. Aryania A, Aghdasi HS, Beccaluva EA et al (2020) Social engagement of children with autism spectrum disorder (asd) in imitating a humanoid robot: a case study. SN Appl Sci 2(6):1–17
4. Aziz AA, Moganan FFM, Ismail A et al (2015) Autistic children's kansei responses towards humanoid-robot as teaching mediator. Procedia Comput Sci 76:488–493

5. Bartneck C, Kulić D, Croft E et al (2009) Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. Int J Soc Robot 1(1):71–81
6. Bekele E, Crittendon JA, Swanson A et al (2014) Pilot clinical application of an adaptive robotic system for young children with autism. Autism 18(5):598–608
7. Bharatharaj J, Huang L, Krägeloh C et al (2018) Social engagement of children with autism spectrum disorder in interaction with a parrot-inspired therapeutic robot. Procedia Comput Sci 133:368–376
8. Boccanfuso L, Scarborough S, Abramson RK et al (2017) A low-cost socially assistive robot and robot-assisted intervention for children with autism spectrum disorder: field trials and lessons learned. Auton Robot 41(3):637–655
9. Boulter C, Freeston M, South M et al (2014) Intolerance of uncertainty as a framework for understanding anxiety in children and adolescents with autism spectrum disorders. J Autism Dev Disord 44(6):1391–1402
10. Brivio A, Rogacheva K, Lucchelli M et al (2021) A soft, mobile, autonomous robot to develop skills through play in autistic children. Paladyn J Behav Robot 12(1):187–198
11. Cao W, Song W, Li X et al (2019) Interaction with social robots: improving gaze toward face but not necessarily joint attention in children with autism spectrum disorder. Front Psychol 10:1503
12. Cho K, Shin C (2011) Caregiving intervention for children with autism spectrum disorders using an animal robot. In: Proceedings of the 6th international conference on Human-robot interaction, pp 399–400
13. Constantino JN, Gruber CP (2012) Social responsiveness scale: SRS-2. Western psychological services Torrance, CA
14. Cooper J (2001) Diagnostic and statistical manual of mental disorders (4th edn, text revision)(dsm–iv–tr) Washington, DC: American psychiatric association 2000. 943 pp.£ 39.99 (hb). isbn 0 89042 025 4. Br J Psychiatry 179(1):85–85
15. Costa S, Resende J, Soares FO, et al (2009) Applications of simple robots to encourage social receptiveness of adolescents with autism. In: 2009 annual international conference of the IEEE engineering in medicine and biology society. IEEE, pp 5072–5075
16. Costa S, Santos C, Soares F, et al (2010) Promoting interaction amongst autistic adolescents using robots. In: 2010 annual international conference of the IEEE engineering in medicine and biology. IEEE, pp 3856–3859
17. Van de Cruys S, Evers K, Van der Hallen R et al (2014) Precise minds in uncertain worlds: predictive coding in autism. Psychol Rev 121(4):649
18. Di Nuovo A, Bamforth J, Conti D, et al (2020) An explorative study on robotics for supporting children with autism spectrum disorder during clinical procedures. In: Companion of the 2020 ACM/IEEE international conference on human–robot interaction, pp 189–191
19. Edition F, et al (2013) Diagnostic and statistical manual of mental disorders. Am Psychiatr Assoc 21
20. Etche Ogeli R, Pradel G, Malen JP (2011) Contribution to the study of assisted interactions between an autistic child and a therapist by the way of a mobile robot in a play situation. In: Everyday technology for independence and care. IOS Press, pp 497–507
21. Fachantidis N, Syriopoulou-Delli CK, Zygopoulou M (2020) The effectiveness of socially assistive robotics in children with autism spectrum disorder. Int J Dev Disabil 66(2):113–121
22. Fletcher-Watson S, Adams J, Brook K et al (2019) Making the future together: shaping autism research through meaningful participation. Autism 23(4):943–953
23. Fox J, Gambino A (2021) Relationship development with humanoid social robots: Applying interpersonal theories to human–robot interaction. Cyberpsychol Behav Soc Netw 24(5):294–299
24. Giannopulu I, Montreynaud V, Watanabe T (2014a) Neurotypical and autistic children aged 6 to 7 years in a speaker-listener situation with a human or a minimalist interactor robot. In: The 23rd IEEE international symposium on robot and human interactive communication. IEEE, pp 942–948
25. Giannopulu I, Montreynaud V, Watanabe T (2014b) Pekoppa: a minimalistic toy robot to analyse a listener-speaker situation in neurotypical and autistic children aged 6 years. In: Proceedings of the second international conference on human-agent interaction, pp 9–16
26. Giannopulu I, Etournaud A, Terada K et al (2020) Ordered interpersonal synchronisation in asd children via robots. Sci Rep 10(1):1–10
27. Golliot J, Raby-Nahas C, Vezina M, et al (2015) A tool to diagnose autism in children aged between two to five old: an exploratory study with the robot queball. In: Proceedings of the tenth annual ACM/IEEE international conference on human–robot interaction extended abstracts, pp 61–62
28. Goulart C, Valadão C, Caldeira E et al (2019) Brain signal evaluation of children with autism spectrum disorder in the interaction with a social robot. Biotechnol Res Innov 3(1):60–68
29. Huijnen CA, Verreussel-Willen HA, Lexis MA et al (2021) Robot kaspar as mediator in making contact with children with autism: a pilot study. Int J Soc Robot 13(2):237–249
30. Huskens B, Verschuur R, Gillesen J et al (2013) Promoting question-asking in school-aged children with autism spectrum disorders: effectiveness of a robot intervention compared to a human-trainer intervention. Dev Neurorehabil 16(5):345–356
31. Ismail LI, Shamsudin S, Yussof H et al (2012) Robot-based intervention program for autistic children with humanoid robot nao: initial response in stereotyped behavior. Procedia Eng 41:1441–1447
32. Jenkinson R, Milne E, Thompson A (2020) The relationship between intolerance of uncertainty and anxiety in autism: a systematic literature review and meta-analysis. Autism 24(8):1933–1944
33. Jeon KH, Yeon SJ, Kim YT, et al (2014) Robot-based augmentative and alternative communication for nonverbal children with communication disorders. In: Proceedings of the 2014 ACM international joint conference on pervasive and ubiquitous computing, pp 853–859
34. Kajopoulos J, Wong AHY, Yuen AWC, et al (2015) Robot-assisted training of joint attention skills in children diagnosed with autism. In: International conference on social robotics. Springer, pp 296–305
35. Karakosta E, Dautenhahn K, Syrdal DS et al (2019) Using the humanoid robot kaspar in a greek school environment to support children with autism spectrum condition. Paladyn J Behav Robot 10(1):298–317
36. Korneder J, Louie WYG, Pawluk CM et al (2021) Robot-mediated interventions for teaching children with asd: a new intraverbal skill. Assist Technol 34:707–716
37. Kostrubiec V, Kruck J (2020) Collaborative research project: developing and testing a robot-assisted intervention for children with autism. Front Robot AI 7:37
38. Kouroupa A, Laws KR, Irvine K et al (2022) The use of social robots with children and young people on the autism spectrum: a systematic review and meta-analysis. PLoS ONE 17(6):e0269,800
39. Kozima H, Michalowski MP, Nakagawa C (2009) Keepon. Int J Soc Robot 1(1):3–18
40. Kumazaki H, Muramatsu T, Yoshikawa Y et al (2019) Job interview training targeting nonverbal communication using an android robot for individuals with autism spectrum disorder. Autism 23(6):1586–1595
41. Kylliäinen A, Jones EJ, Gomot M et al (2014) Practical guidelines for studying young children with autism spectrum disorder in psychophysiological experiments. Rev J Autism Dev Disorders 1(4):373–386

42. Landon J, Shepherd D, Lodhia V (2016) A qualitative study of noise sensitivity in adults with autism spectrum disorder. Res Autism Spectr Disorders 32:43–52
43. Leekam SR, Libby SJ, Wing L et al (2002) The diagnostic interview for social and communication disorders: algorithms for icd-10 childhood autism and wing and gould autistic spectrum disorder. J Child Psychol Psychiatry 43(3):327–342
44. Leekam SR, Nieto C, Libby SJ et al (2007) Describing the sensory abnormalities of children and adults with autism. J Autism Dev Disord 37(5):894–910
45. Leekam SR, Prior MR, Uljarevic M (2011) Restricted and repetitive behaviors in autism spectrum disorders: a review of research in the last decade. Psychol Bull 137(4):562
46. Lord C, Rutter M, Goode S et al (1989) Austism diagnostic observation schedule: a standardized observation of communicative and social behavior. J Autism Dev Disord 19(2):185–212
47. Lord C, Rutter M, Le Couteur A (1994) Autism diagnostic interview-revised: a revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. J Autism Dev Disord 24(5):659–685
48. Lough CL, Rice MS, Lough LG (2012) Choice as a strategy to enhance engagement in a colouring task in children with autism spectrum disorders. Occup Ther Int 19(4):204–211
49. Louie WYG, Korneder J, Abbas I et al (2021) A study on an applied behavior analysis-based robot-mediated listening comprehension intervention for asd. Paladyn J Behav Robot 12(1):31–46
50. Malik NA, Shamsuddin S, Yussof H, et al (2013) Feasibility of using a humanoid robot to elicit communicational response in children with mild autism. In: IOP conference series: materials science and engineering. IOP Publishing, p 012077
51. Miskam MA, Hamid MAC, Yussof H, et al (2013) Study on social interaction between children with autism and humanoid robot nao. In: Applied mechanics and materials, Trans Tech Publ, pp 573–578
52. Ouzzani M, Hammady H, Fedorowicz Z et al (2016) Rayyan-a web and mobile app for systematic reviews. Syst Rev 5(1):1–10
53. Page MJ, McKenzie JE, Bossuyt PM et al (2021) Updating guidance for reporting systematic reviews: development of the prisma 2020 statement. J Clin Epidemiol 134:103–112
54. Pellicano E, Burr D (2012) When the world becomes 'too real': a Bayesian explanation of autistic perception. Trends Cognit Sci 16(10):504–510
55. Petric F, Miklić D, Cepanec M, et al (2017) Functional imitation task in the context of robot-assisted autism spectrum disorder diagnostics: Preliminary investigations. In: 2017 26th IEEE international symposium on robot and human interactive communication (RO-MAN). IEEE, pp 1471–1478
56. Pliasa S, Fachantidis N, Maragkou P (2020) Can children of typical development benefit from inclusion intervention with daisy robot-a socially assistive robot? In: 9th international conference on software development and technologies for enhancing accessibility and fighting info-exclusion, pp 235–240
57. Pop CA, Simut RE, Pintea S et al (2013) Social robots vs. computer display: does the way social stories are delivered make a difference for their effectiveness on asd children? J Educ Comput Res 49(3):381–401
58. Pour AG, Taheri A, Alemi M et al (2018) Human-robot facial expression reciprocal interaction platform: case studies on children with autism. Int J Soc Robot 10(2):179–198
59. Qidwai U, Kashem SBA, Conor O (2020) Humanoid robot as a teacher's assistant: helping children with autism to learn social and academic skills. J Intell Robot Syst 98(3):759–770
60. Rahman MM, Ferdous S, Ahmed SI (2010) Increasing intelligibility in the speech of the autistic children by an interactive computer game. In: 2010 IEEE international symposium on multimedia. IEEE, pp 383–387
61. Raptopoulou A, Komnidis A, Bamidis PD et al (2021) Human–robot interaction for social skill development in children with asd: a literature review. Healthc Technol Lett 8:90–96
62. Robins B, Dautenhahn K, Te Boerkhorst R, et al (2004a) Robots as assistive technology-does appearance matter? In: RO-MAN 2004. 13th IEEE international workshop on robot and human interactive communication (IEEE Catalog No. 04TH8759). IEEE, pp 277–282
63. Robins B, Dickerson P, Stribling P et al (2004) Robot-mediated joint attention in children with autism: a case study in robot–human interaction. Interact Stud 5(2):161–198
64. Robins B, Dautenhahn K, Te Boekhorst R et al (2005) Robotic assistants in therapy and education of children with autism: can a small humanoid robot help encourage social interaction skills? Univ Access Inf Soc 4(2):105–120
65. Robins B, Dickerson P, Dautenhahn K (2005b) Robots as embodied beings-interactionally sensitive body movements in interactions among autistic children and a robot. In: ROMAN 2005. IEEE international workshop on robot and human interactive communication, 2005. IEEE, pp 54–59
66. Robins B, Dautenhahn K, Dubowski J (2006) Does appearance matter in the interaction of children with autism with a humanoid robot? Interact Stud 7(3):479–512
67. Robins B, Dautenhahn K, Dickerson P (2012) Embodiment and cognitive learning–can a humanoid robot help children with autism to learn about tactile social behaviour? In: International conference on social robotics. Springer, pp 66–75
68. Saadatzi MN, Pennington RC, Welch KC et al (2018) Small-group technology-assisted instruction: virtual teacher and robot peer for individuals with autism spectrum disorder. J Autism Dev Disord 48(11):3816–3830
69. Schadenberg BR, Reidsma D, Heylen DK et al (2020) Differences in spontaneous interactions of autistic children in an interaction with an adult and humanoid robot. Front Robot AI 7:28
70. Schopler E, Reichler RJ, DeVellis RF, et al (1980) Toward objective classification of childhood autism: childhood autism rating scale (cars). J Autism Dev Disorders
71. Shamsuddin S, Yussof H, Mohamed S, et al (2013) Stereotyped behavior of autistic children with lower iq level in hri with a humanoid robot. In: 2013 IEEE workshop on advanced robotics and its social impacts. IEEE, pp 175–180
72. Short ES, Deng EC, Feil-Seifer D et al (2017) Understanding agency in interactions between children with autism and socially assistive robots. J Hum–Robot Interact 6(3):21–47
73. Simut RE, Vanderfaeillie J, Peca A et al (2016) Children with autism spectrum disorders make a fruit salad with probo, the social robot: an interaction study. J Autism Dev Disord 46(1):113–126
74. Smith E, Sumner P, Hedge C, et al (2020) Smart-speaker technology and intellectual disabilities: agency and wellbeing. Disabil Rehabil Assist Technol pp 1–11
75. Soleiman P, Moradi H, Mehralizadeh B, et al (2020) Robotic social environments: a promising platform for autism therapy. In: International conference on social robotics. Springer, pp 232–245
76. Tapus A, Peca A, Aly A et al (2012) Children with autism social engagement in interaction with nao, an imitative robot: a series of single case experiments. Interact Stud 13(3):315–347
77. Wagemaker E, Dekkers TJ, Agelink van Rentergem JA et al (2017) Advances in mental health care: five n= 1 studies on the effects of the robot seal paro in adults with severe intellectual disabilities. J Mental Health Res Intell Disabil 10(4):309–320
78. White AN, Oteto NE, Brodhead MT (2022) Providing choice-making opportunities to students with autism during instruction. Teach Except Child 00400599211068386
79. Wing L, Leekam SR, Libby SJ et al (2002) The diagnostic interview for social and communication disorders: background, inter-rater reliability and clinical use. J Child Psychol Psychiatry 43(3):307–325

80. Yin TC, Tung FW (2013) Design and evaluation of applying robots to assisting and inducing children with autism in social interactioncao2019interaction. In: International conference on universal access in human-computer interaction. Springer, pp 524–533
81. Zhang Y, Song W, Tan Z et al (2019) Theory of robot mind: false belief attribution to social robots in children with and without autism. Front Psychol 10:1732
82. Zhang Y, Song W, Tan Z et al (2019) Could social robots facilitate children with autism spectrum disorders in learning distrust and deception? Comput Hum Behav 98:140–149

Dr Christopher D. Wallbridge is currently a lecturer at the School of Computer Science and Informatics at Cardiff University, with his work focusing on Human-Robot Interaction. Chris holds an MSc in Robotics and studied for his PhD at Plymouth University. His research has included working to teach children a second language using robots, improving communication between robots and people in cooperative environments and now focuses on increasing trust and safety between robots and people.

Carly McGregor is a PhD student at the School of Psychology at Cardiff University. She completed her undergraduate degree at Duke University, where she studied psychology and computer science. Her research focuses on how autistic children experience social timing, and how they interact with humanoid robots.

Natalia Drozdz has an MSc in Psychology from Cardiff University.

Dr Elisabeth von dem Hagen is a senior lecturer in the School of Psychology at Cardiff University. Elisabeth holds an MSc in Medical Physics from the University of Toronto, and a PhD in Psychology from the Royal Holloway University of London. Elisabeth's work focuses on social information processing using both behavioural and neuroimaging approaches. She is interested in how processing of these signals may changing during a child's development, and also how it may differ in autistic people.

Dr Catherine Jones is a Reader in the School of Psychology, Cardiff University and also Director of Cardiff University's Wales Autism Research Centre. She completed her undergraduate degree in Psychology at University College London, followed by a PhD in Cognitive Neuroscience at the UCL Institute of Neurology. Catherine's research focuses on better understanding the experiences and perspectives of autistic people, including their sensory experiences and the temporal dynamics of their interactions. She is also interested in the impact of co-occurring conditions on autistic people, particularly eating disorders.