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Attention shifting during child–robot interaction: a preliminary clinical study for children with autism spectrum disorder

Key words: Human–robot interaction; Robot-enhanced therapy; Socially interactive robots; Robot-mediated intervention

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Motivation

1. For physical robot design, future studies should investigate whether robots with a touch screen are suitable for robot-enhanced therapy for autism.

2. For evaluations of robots in therapy-like settings, future studies should apply more reliable and robust methods for automated video coding in autism data analysis.

3. In this study, we investigate what are the preferences of children with ASD and their parents for appearances and functionalities of the robots during the interaction and how to qualitatively analyze and quantitatively measure the prosocial behaviors and actions performed by children with ASD during the interaction.

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Main idea

1. First, for physical robot design, we investigate whether robots with a touch screen are suitable for robot-enhanced therapy for autism using three different robots that all have a touch screen but differ in appearance and functionality.

2. Second, for evaluations of robots in therapy-like settings, we apply a more reliable, robust, and objective method for quantitative data analysis by adopting algorithms such as face detection and filtering and estimation of the directions of gaze and head posture for automated attention analysis based on recorded videos.

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Method—procedure

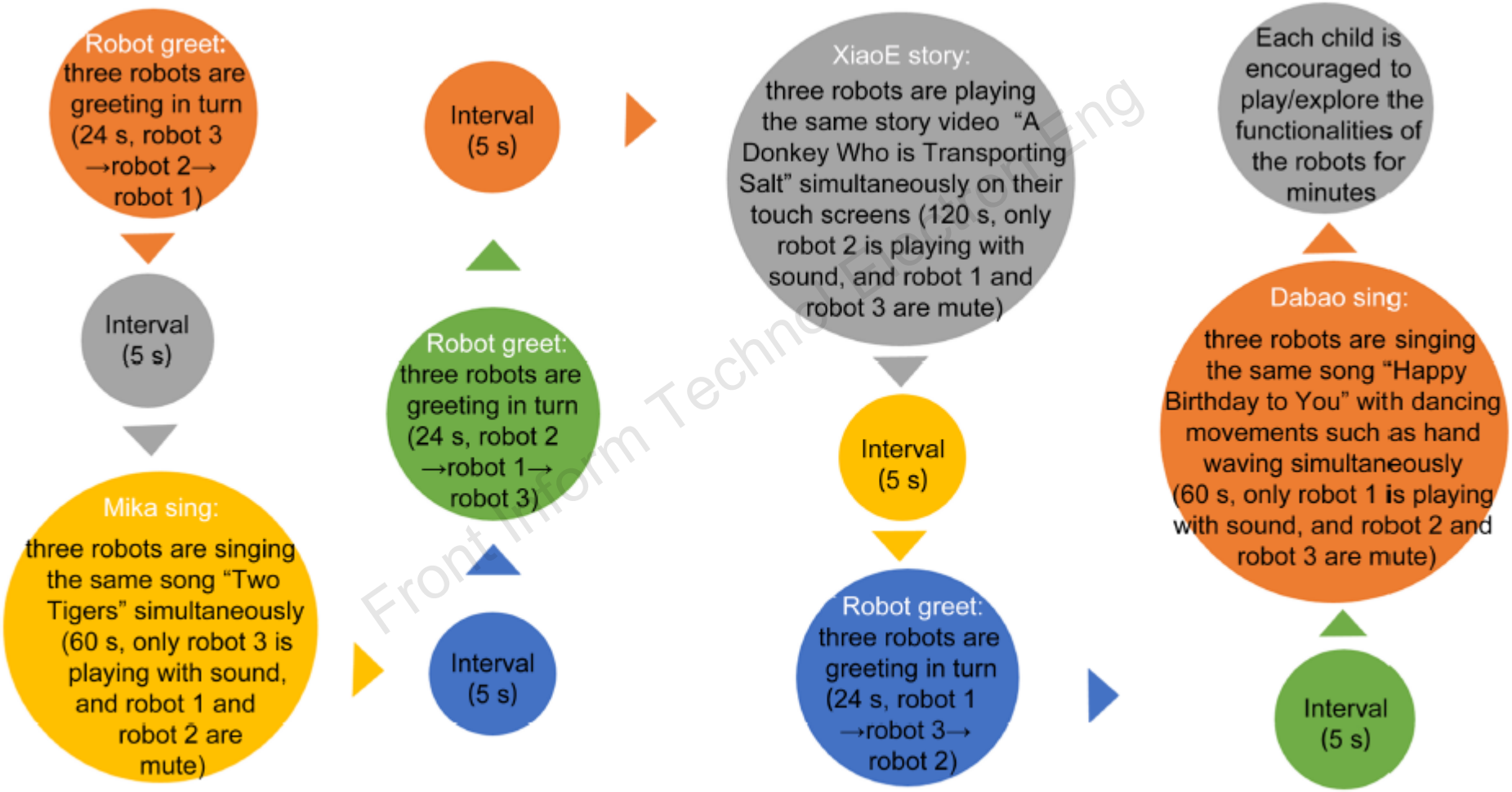

Fig. 1 Procedure of human–robot interaction (Dabao: robot 1; XiaoE: robot 2; Mika: robot 3)

Method—Study set up

Four different rehabilitation facilities/institutions are ASD Rehabilitation Training Center for Children, Shenzhen Maternal & Child Healthcare Hospital (MCH), and three branches of Zi Fei Yu Rehabilitation Training Center for Autistic Children (i.e., Futian, Meilin, and Longhua branches), Shenzhen.

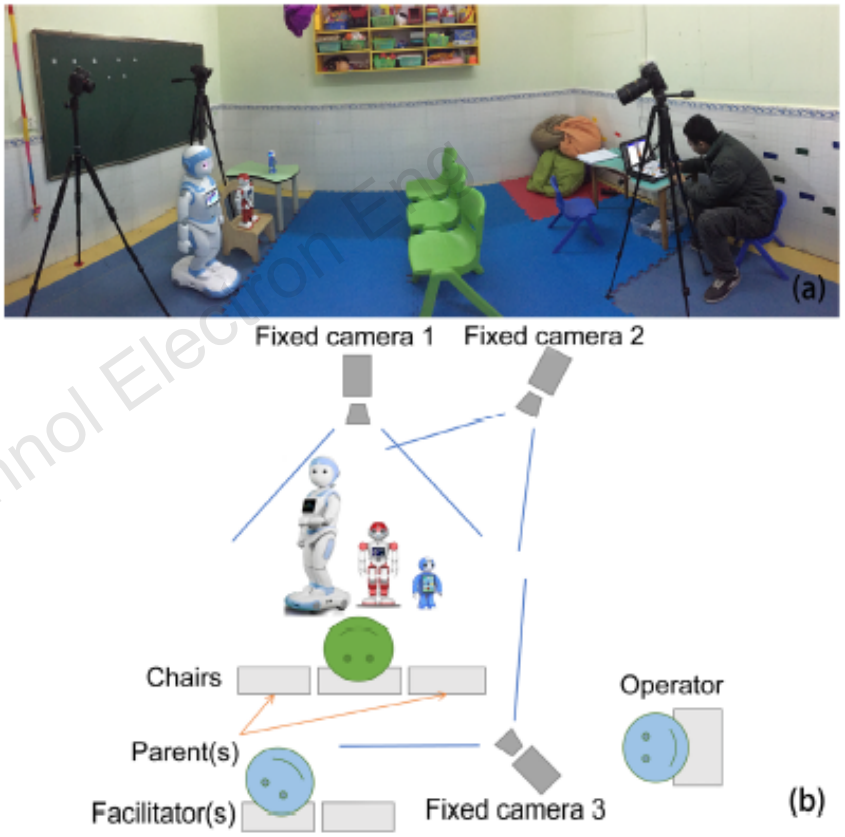

Fig. 2 Study setup in one of the four different rehabilitation facilities (a) and an example of how cameras were set in a quiet room (b)
The child sitting in the middle chair is indicated with green color with parent(s) sitting next to him/her. References to color refer to the online version of this figure

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Method—data collection and participants

Data was collected from two types of materials. One is the questionnaires filled in mostly by parents except a few professionals who accompanied the participants in the whole session, and the other is the videos recorded by the three cameras. The video recorded during each session can be divided into two parts, namely the "watching part" in which each child only watched the robots performing, and the "exploring part" in which each child was encouraged to explore the functionalities of the robots. In each session, parents/professionals were asked to fill in a questionnaire in Chinese along with a consent form for video recording, either in the watching part or in the exploring part after each session.

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Table 1 Effective samples and purposes of questionnaires and videos

Materials		Effective sample	Purpose
Questionnaires		Totally 63: 44 ASD children, 18 DD children, and one TD child	To seek insights on how to design socially interactive robots for ASD therapy that can fit the preferences of parents with ASD child/children for appearances and functionalities of the robots
Videos	Watching part	Totally 56: 40 ASD children, 14 DD children, and two TD children (one sibling accompanying her little brother was not counted as a participant, whose video was effective in this part)	To perform attention analysis using software to automatically detect each child's gaze and head pose direction in video clips, to find out which robot and what functionalities of the robot interested the children with ASD
	Exploring part	Totally 70: 50 ASD children, 18 DD children, one TD child, and one NYD child	By observing the video clips to calculate how interested, for how much time, and what functionalities the children played with the three robots

ASD: autism spectrum disorder; DD: developmental delay; TD: typical development; NYD: not-yet-diagnosed

Method—data analysis

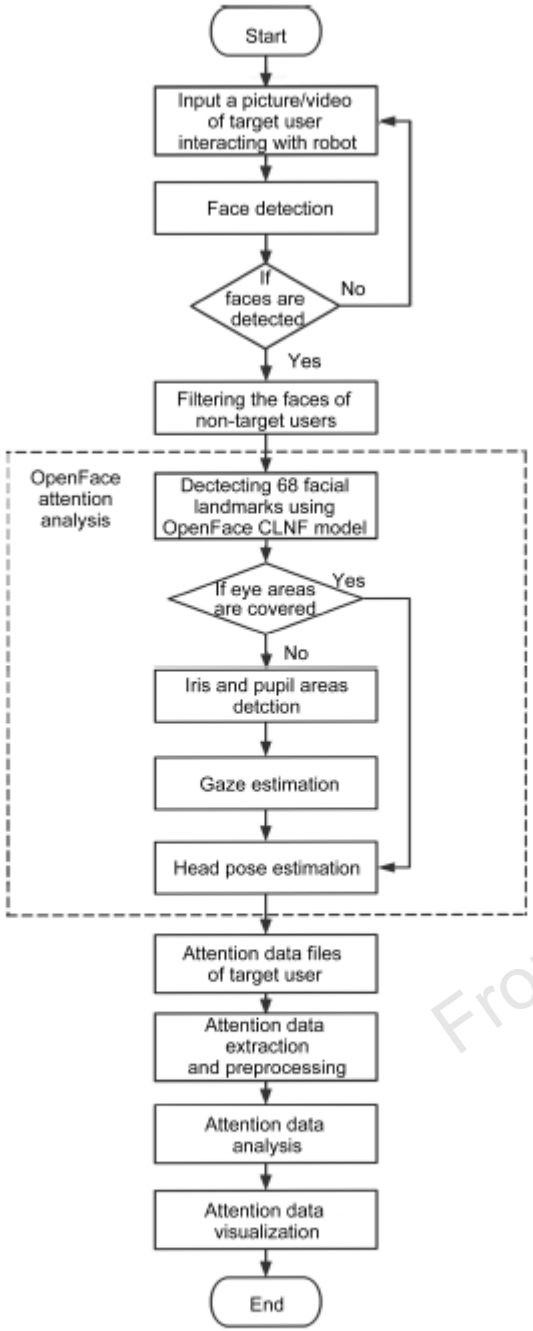

Fig. 3 Flowchart of attention analysis
CLNF: conditional local neural field

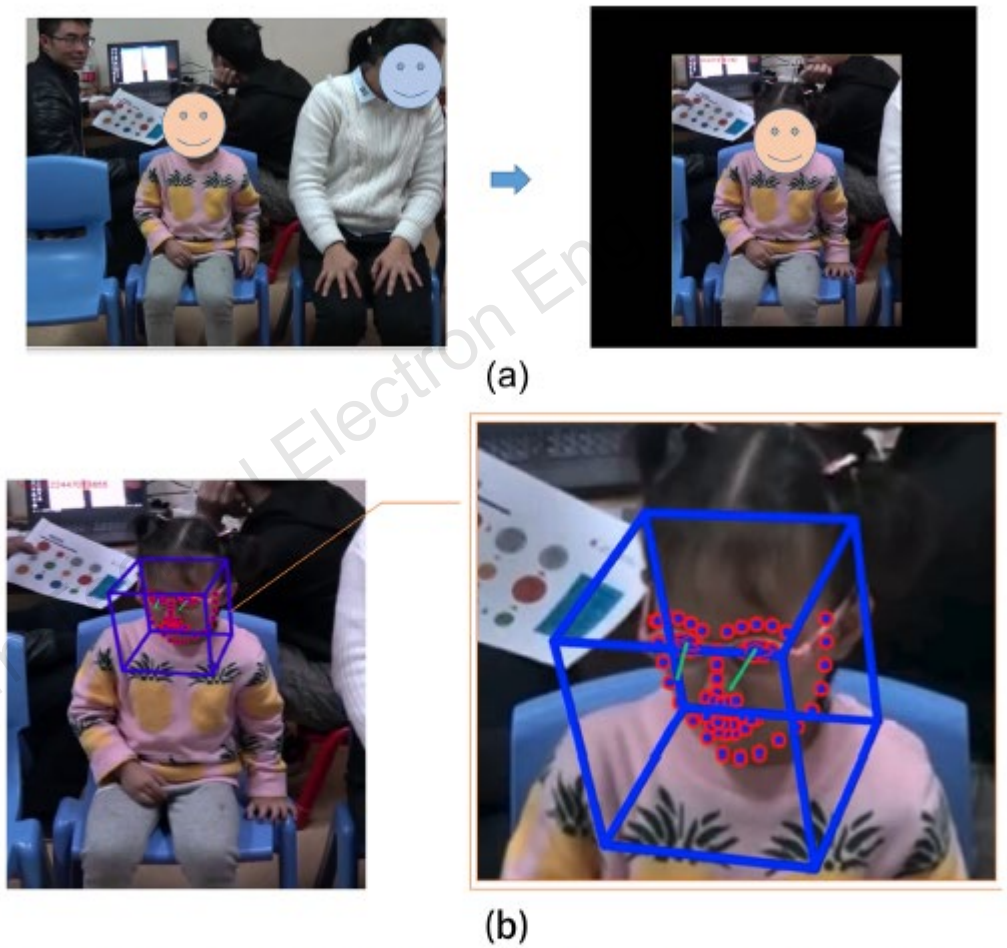

Fig. 4 Non-target user filtering (a) and attention analysis of the targeted user (b)
Red dots represent the facial feature points, blue frame indicates the estimated head posture direction, and green line indicates the estimated gaze direction. References to color refer to the online version of this figure

Method—Data analysis

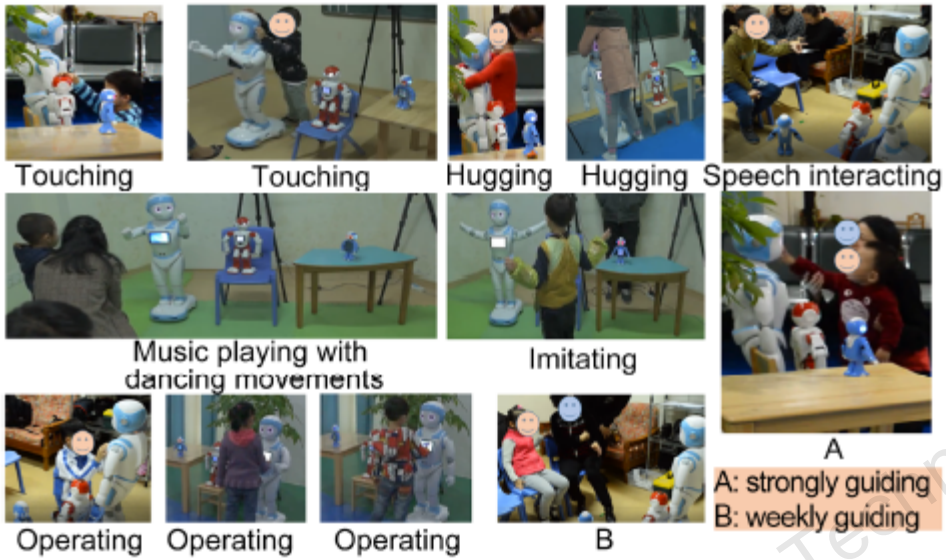

Fig. 6 Examples of how children with ASD/DD interacted with the robots in the exploring part of videos

ASD: autism spectrum disorder; DD: developmental delay

In the exploring part the of videos, video analysis was done by observing how each participant interacted with the robots in the video clips (Fig. 6). To calculate the degree of preferences of children with ASD or DD for playing with each of the three robots, some parameters were defined (Table 3).

Table 3 Parameters on the degree of preference of children with ASD or DD for playing with robots

Parameter	Description
T	Time given to each child to explore/play with the functionalities of the three robots (the facilitator(s) instructed the parents to start or to end exploring before the parents instructed their children)
T_e	Time that each child actually spent on exploring/playing with the three robots, i.e., time that each child spent on touching, operating, and imitating one particular robot, or observing the robot at a very close distance, etc. (Fig. 6) during T
T_1	Time each child actually spent on exploring/playing with robot 1 (Dabao) during T_e
T_2	Time each child actually spent on exploring/playing with robot 2 (XiaoE) during T_e
T_3	Time each child actually spent on exploring/playing with robot 3 (Mika) during T_e
P	The score/degree of preference of children with ASD or DD for playing with the three robots: $P=100T_e/T$.
P_{1r}	The relative score/degree of preference of children with ASD or DD for playing with robot 1: $P_{1r}=100T_1/T_e$.
P_{1a}	The absolute score/degree of preference of children with ASD or DD for playing with robot 1: $P_{1a}=P_{1r}P/100$.

ASD: autism spectrum disorder; DD: developmental delay. Similarly, the relative and absolute preferences for robot 2 and robot 3 can be expressed as (P_{2r}, P_{2a}) and (P_{3r}, P_{3a}), respectively

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Major results—Insights of questionnaires analysis

The simple statistical analysis of the questionnaires indicates that most of children with ASD or DD are male, and most of the parents tending them are female. Furthermore, parents with ASD or DD children have more or less the same expectation on the following aspects:

1. Appearances of children companion robots: most of the parents hope that the color of the robot is bright and warm.
2. Functionalities of children companion robots: most of parents expect the robots to be enthusiastic, smart, and cute, and hope that robots can accompany their children to play.
3. Acceptance of children companion robots: most of the parents accept the robots and hope the prices of the robots to be lower than 5000 RMB.

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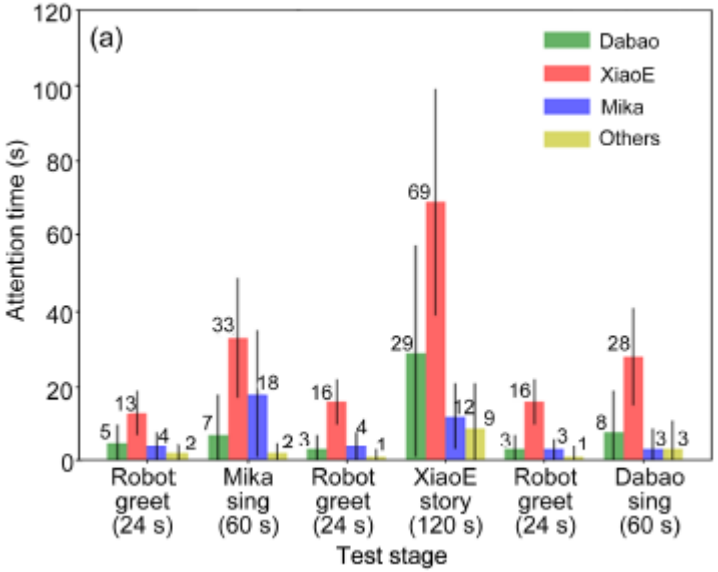
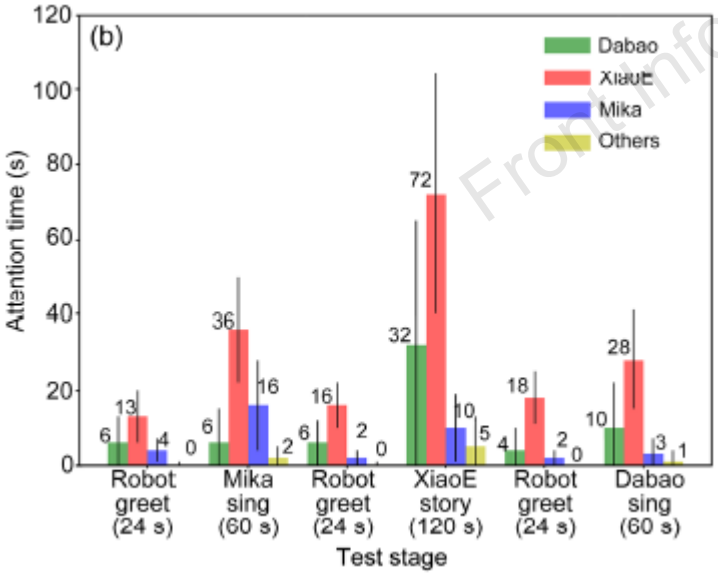
Major results—Insights of video analysis: the watching part





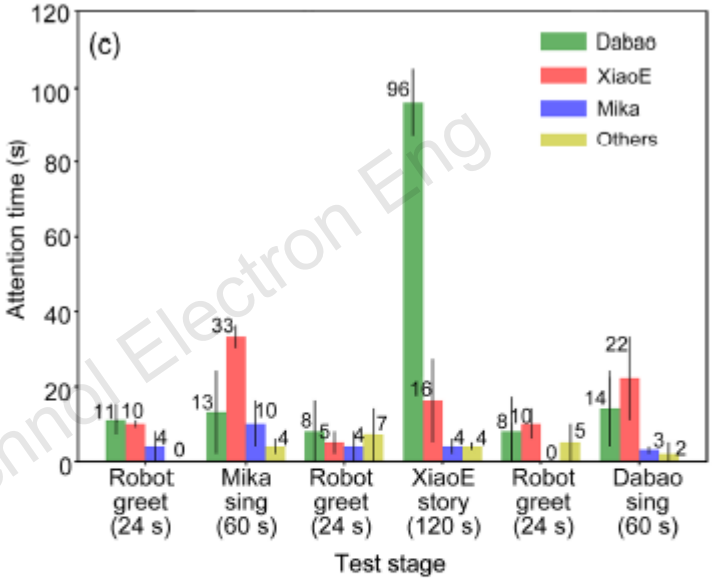


Fig. 7 Average attention bar graph with variance for 40 ASD children samples (a), 14 DD children samples (b), and two TD children samples (c)

ASD: autism spectrum disorder; DD: developmental delay; TD: typical development. References to color refer to the online version of this figure

SPSS variance analysis indicated that in the watching part, children with ASD or DD focused on robot 2 (XiaoE) most of the time.

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Major results—Insights of video analysis: the watching part

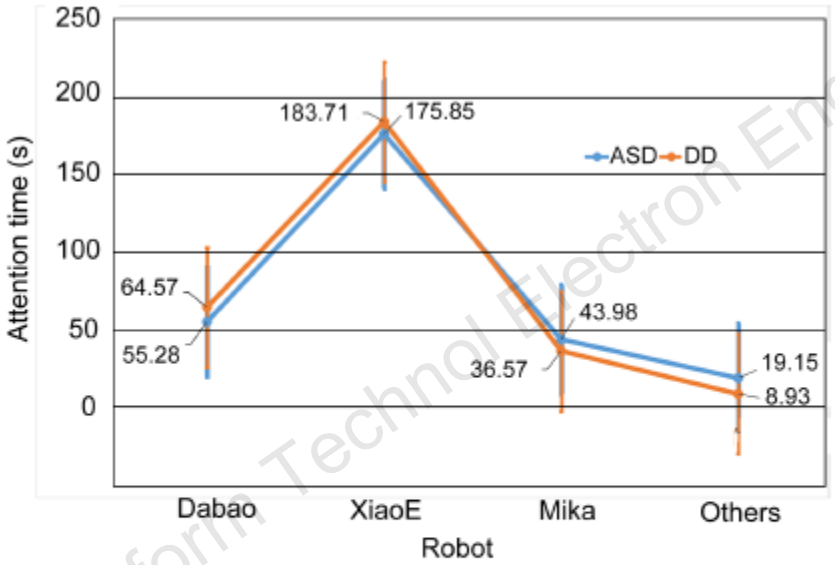

Fig. 8 Patterns in paying attention to different robots for ASD children and DD children

ASD: autism spectrum disorder; DD: developmental delay. References to color refer to the online version of this figure

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When watching the robots performing the six sequential robotic behaviors, ASD children shared similar patterns with DD children. After performing a SPSS variance analysis (general liner model to multivariate) of the attention time nodes of 40 ASD children samples and of 14 DD children samples, no significant difference was found in the attention of the two different groups to the three different kinds of robots.

Major results—Insights of video analysis: the exploring part

Table 4 Scores of relative and absolute preferences for robots 1, 2, and 3 without considering the influence of parental guidance

Sample	Relative (P_{nr}) and absolute (P_{na}) preferences for the three robots (n=1, 2, 3)					
	Robot 1		Robot 2		Robot 3	
	P_{1r}	P_{1a}	P_{2r}	P_{2a}	P_{3r}	P_{3a}
50 ASD children	60.3	42.1	15.0	10.6	16.6	9.8
18 DD children	54.3	32.8	16.5	10.1	23.8	15.6
One TD child	23.4	21.2	22.4	20.3	54.2	49.1
One NYD child	9.7	8.4	19.8	17.1	70.5	60.7
Total (70 samples)	57.5	38.9	15.6	10.7	19.7	12.6

ASD: autism spectrum disorder; DD: developmental delay; TD: typical development; NYD: not-yet-diagnosed

Table 5 Scores of the relative and absolute preferences for robots 1, 2, and 3 considering the influence of parental guidance

Sample	Relative (P_{nr}) and absolute (P_{na}) preferences for the three robots (n=1, 2, 3)					
	Robot 1		Robot 2		Robot 3	
	P_{1r}	P_{1a}	P_{2r}	P_{2a}	P_{3r}	P_{3a}
40 children without parents' guide (28 ASD and 10 DD)	56.3	41.4	17.6	13.5	25.3	18.4
22 children with parents' strong guide (15 ASD and 7 DD)	28.4	18.2	6.3	3.5	6.2	2.3
8 children with parents' weak guide (7 ASD and one DD)	47.4	23.1	11.6	6.1	7.3	2.4
Total (70 samples)	44.0	27.6	11.8	7.7	12.9	7.7

ASD: autism spectrum disorder; DD: developmental delay; TD: typical development

As indicated by Tables 4 and 5, among all these three robots being different in terms of size, color, appearance, and so on, robot 1 is the most attractive.

Table 6 Functionalities of the robots children played with most

Functionality	Frequency/ person-time
Touching sensing with a feedback	39
Operating (e.g., finding games to play or videos to watch)	31
Singing and dancing	13
Speech interacting	5
Imitating	4
Hugging	3

It is worth mentioning that most of the functionalities listed in Table 6 were observed as the functionalities of robot 1 (Dabao). This highlights the importance of equipping a touching sensing with feedback functionality and an appropriate size of touch screen for robots for ASD therapy.

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Conclusions

1. With respect to physical robot design, when doing physical robot design, some aspects of appearance (e.g., with an appropriate size of touch screen to operate) and some functionalities (e.g., a touching sensing functionality to provide interactive feedback) should be taken into account.

2. For evaluation of robots in therapy-like settings, on one hand, attention analysis using algorithms such as face detection and filtering, and estimation of the directions of gaze and head posture can be adopted to quantitatively measure the prosocial behaviors and actions performed by the children with ASD during the interventions; on the other hand, observing and calculating the time children spend on exploring/playing with the robots in video clips can be adopted to qualitatively analyze the behaviors and actions of such children.

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