The Effect of Simple Emotional Gesturing in a Socially Assistive Robot on Child's Engagement at a Group Vaccination Day

Anouk Neerincx
Utrecht University
Utrecht, The Netherlands
a.neerincx@uu.nl

Jessica Leven
Utrecht University
Utrecht, The Netherlands
j.leven@students.uu.nl

Pieter Wolfert
Ghent University - imec
Ghent, Belgium
pieter.wolfert@ugent.be

Maartje M.A. de Graaf
Utrecht University
Utrecht, The Netherlands
m.m.a.degraaf@uu.nl

ABSTRACT

Children encounter high levels of stress and anxiety before receiving medical treatment, such as a vaccination. This paper explores the effect of emotional gesturing in socially assistive robots (SARs) on children's observed and self-reported engagement, as well as self-reported anxiety, fear, and trust during a group vaccination. A total of 249 children interacted with the social robot iPal before and after receiving the vaccine. Our results show an overall positive effect of adding emotional gestures to a SAR's interaction behavior leading to increased engagement and lower anxiety, while increased engagement also resulted in trusting the robot more. Thus, adding emotional gestures during child-robot interaction is a powerful way to improve the child's experience during a group vaccination day.

CCS CONCEPTS

• **Computer systems organization → Robotics**; • **Human-centered computing → Field studies**.

KEYWORDS

emotional gestures, child-robot interaction, field study

ACM Reference Format:
Anouk Neerincx, Jessica Leven, Pieter Wolfert, and Maartje M.A. de Graaf. 2023. The Effect of Simple Emotional Gesturing in a Socially Assistive Robot on Child's Engagement at a Group Vaccination Day. In *Proceedings of the 2023 ACM/IEEE International Conference on Human-Robot Interaction (HRI '23), March 13–16, 2023, Stockholm, Sweden.* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3568162.3576960

1 INTRODUCTION

The application of socially assistive robots (SARs) in child healthcare has been increasingly researched and deployed as they offer substantial benefits such as assisting children in managing chronic illness [21] or distracting children undergoing medical procedures (e.g., vaccinations [41]). Using social robots for emotional support in children has several benefits. The relationship between a social robot and a child differs from the relationship between a child and a healthcare professional. A social robot can take on the role of a peer [47] making it less scary to talk to compared to an (adult) healthcare worker. In this way, a social robot can be used to break the ice between child and healthcare professional [37]. Additionally, in some medical settings such as group vaccinations, healthcare professionals lack the time for reaching out to all children. Here, social robots could assist in providing emotional support.

Increased engagement facilitates distracting children from stressful situations [31] such as the waiting room before vaccination. To achieve the goal of engaging humans more with robots, they should be equipped with sophisticated social skills [3]. Despite the evident health benefits resulting from a SAR's ability for social interaction (e.g., by talking, changing posture, and gesturing), designing particular sociable traits such as conveying information about emotions as an act of adaption and response to individuals' needs or moods remains complicated [4]. Getting people to initially engage with a robot is easy, but keeping them engaged over time –regarding the present interaction but also beyond one interaction– prevails a challenge [53]. Yet, a robot lacking appropriate social skills may hurt the child's perception and trust, which, in turn, threatens user engagement and long-term acceptance [10].

The fields of Human-Robot Interaction (HRI) and Intelligent Virtual Agents (IVA) has accumulated research on socially expressive behavior in the past decades [11]. For example, in designing an architecture for generating synchronized speech and gestures in a natural way [26], expressing emotional states and intentions through verbal and nonverbal behaviors for social awareness [8], generating socially appropriate speech and motions based on sensory data of human-human interactions [29], or designing multi-modal, long-term, adaptive social HRI for children [5]. Particularly relevant for our current study is a focus on body movements and gestures that contain information about the sender such as affect, personality and/or style [51]. Gestures are a form of nonverbal communication in human interactions that not only aid people to convey emotions along with its intensity themselves but also enable people to infer and judge emotions expressed by others [13]. Several studies have investigated the effect of (emotional) gestures on user engagement. For example, robots that use gestures were better able to keep the user's attention and interactions with gestures were perceived as

HRI '23, March 13–16, 2023, Stockholm, Sweden

ACM ISBN 978-1-4503-9964-7/23/03…$15.00
https://doi.org/10.1145/3568162.3576960

more appropriate than when gestures were absent during interactions [45]. Somewhat similar, Hall et al. [20] found that people rate a gesture-using robot as more socially engaging and understandable, however people's self-reported engagement does not increase due to the use of gestures but is rather a result from familiarity with robotics. Other studies have concluded that especially the correct timing of gestures (i.e., when users' nonverbal behavior indicated distraction) were important to keep participant engaged in the conversation [9, 48]. Although engagement has been widely researched in HRI, its effects remain elusive in many different situations and contexts [34]. To explore the specific effect of using gestures in child mental healthcare, our first research question is:

RQ1: How does emotional gesturing in a socially assistive robot influence child engagement and interaction during a group vaccination event?

Not only context or user characteristics influence the child's attentive state and subsequently the engagement, but also emotions. Indeed, previous findings in HRI research indicate the importance of adapting the use of nonverbal behavior to user characteristics, especially emotion-based adaptations, to sustain social engagement during the interaction [1, 36, 50]. Emotions especially play an important role during medical procedures (e.g., vaccinations) where different negative emotions are often present (e.g., anxiety and fear). For example, Jacobson et al. [22] found that nearly half of young children experienced serious distress during and before a vaccination. Based on previous findings [31, 41], we expect that including emotional gestures in the interaction will result in children being more engaged, which in its turn will lower anxiety and fear. Moreover, given that the social robot deployed in our study will inform the children on the procedure, it is important to take trust into account when evaluating the effectiveness of the social robot intervention at the vaccination day [58]. To investigate how anxiety, fear and trust are affected by the implementation of emotional gestures in HRIs, and how such gestures influence engagement, our second research question is composed of two parts:

RQ2a: How does emotional gesturing in a socially assistive robot influence child's anxiety, fear, and trust during a group vaccination event?

RQ2b: What are the effects of child's anxiety, fear, and trust on child's engagement during an interaction with a socially assistive robot?

To study the effects of emotional gesturing in socially assistive robots on engagement, anxiety, fear, and trust in a real-world setting in the child healthcare domain, we have deployed a social robot during two annual group vaccination events.

2 RELATED WORK

Due to abundant benefits of social robots (e.g., productivity, efficiency), the healthcare sector, and more specifically the child and elderly care sector, has developed an increasing interest in deploying such socially interactive agents [15]. In this domain, social robots are often referred to as socially assistive robots (SAR), given that they appropriate an assistive role with hands-off interaction featuring speech, facial expressions, and communicative gestures [16]. In order to be effective in a healthcare setting, SARs have to be equipped with proper social behaviors and the ability to show nonverbal behavior besides the ability to speak. Earlier research calls for an appropriate design of SARs in combination with personalization [1, 50], especially when SARs are used with children [53]. Another requirement is that a SAR should be able to provide a comfortable experience for children, since this forms the basis for trust and bonding [37]. A variety of social robots have been used as a SAR, for example the NAO robot, RP-7 Remote Presence Robot, Keepon, COLOLO, and Pleo [27]. These robots have been applied in various fields, but predominantly for mental health interventions. Here, the SAR can act as a therapeutic intervention [32] or provide social skill training for children with autism spectrum disorder [57].

2.1 Emotional Gestures in Social Robots

Social robots have demonstrated to be capable of influencing the emotions of humans, so called 'mood contagion' [55], which in turn can lead to a higher engagement of participants with social robots. In a study by Tielman et al. [50], children played a quiz with both an affective and a non-affective social robot. In the affective condition the robot would display emotions in reaction to the child's emotional state through verbal and nonverbal channels, more specifically gestures. Children were observed to be more expressive towards the affective robot than to the non-affective robot, and the children rated showing emotions through gestures as a very positive trait for a social robot. It is important to note that the size of the gestures the robot used was influenced by both arousal and extroversion. Work by Ahmad et al. [1] has analyzed whether providing emotional feedback would lead to sustained social engagement in children who are taught vocabulary. In this study, the emotional state of the child was taken into account for the feedback towards the child. This feedback consisted of verbal statements and corresponding emotional induced gestures. The researchers found that incorporating positive emotional feedback had a positive effect on the child's learning performance. These two exemplar child-robot interaction (CRI) studies indicate that including nonverbal behavior such as gestures seems to positively affect social engagement and learning while personalizing of those gestures further increases those effects.

2.2 SARs for Vaccinations

One of the applications of SARs is to use them for distraction during an interaction where a patient undergoes a medical procedure. Fowler-Kerry and Lander [17] investigated the effect of music on the perceived pain level of injections and distress. They found that using music as a distraction technique could lower the pain perception in children, however, the effect of music was lower in younger children. The authors argued that perhaps younger children would show a lower pain perception when other, more interactive distraction techniques are applied. Maybe the application of SARs in paediatric healthcare could offer such interactive distractions leading to more positive effects specifically during the administration of a vaccination in children?

A study by Beran et al. [6, 7] explored the effect of the presence of a robot (NAO robot) during the administration of a flu vaccination to children in a Wizard Of Oz approach (WoZ). In the experimental condition, the robot engaged in small-talk about movies after which it would ask for a high five before the procedure. During the procedure, the robot tried to distract the child by asking it to blow off dust of a rubber duck, and, after the procedure, the robot would thank the child and comment on it's bravery. The control condition did not feature a robot. The researchers found that deploying a robot in the whole process resulted in longer smiles on children's' faces than in the no-robot condition, while the amount and duration of crying remained similar between conditions.

Jibb et al. [23] investigated distraction strategies used by a social robot (MEDiPORT, based on the NAO robot) during needle insertions in children with cancer. To distract the children before the procedure, the robot provided supportive statements in preparation for the procedure as well as calming and encouraging statements right before the procedure. During the procedure, the robot practiced deep breathing exercises with the child. After the procedure had ended, the robot continued providing positive affirmations. The control condition featured the same robot, but in this case the robot only provided an introductory statement followed with dancing and singing by the robot. The researchers reported low distress ratings for both robot distracting behaviors with no significant differences between the two robot conditions, while a no-robot condition was not part of their study design.

Rossi et al. [41] looked at the impact of emotional distraction with a social robot during the administration of a flu vaccine on children's anxiety. They applied human-human distraction strategies with a robot directed at children. The robot used emotional behaviors, with a positive or negative valence, dependent on the initial anxiety state of a child. The researchers found that using a robot with distraction strategies during vaccination reduced fear, anxiety, and pain perception in children.

These four studies indeed demonstrate the possibilities of providing a more comfortable experience for children during a medical procedure, and more specifically in the case of administering a vaccine. However, previous research focuses on using social robots as a distraction during receiving the vaccine itself. Given that children experience most anxiety before the onset of the procedure [22], and social robots show potential for usage in the waiting room [35], we specifically aim to deploy a robot intervention before the vaccination procedure during the waiting time in our current study. Additionally, previous research suggests that using positive emotional gestures can increase the levels of distraction through heightening engagement and increasing positive emotions. Therefore, we decided to compare an expressive robot with a non-expressive robot in terms of gestures.

3 METHODS

In this paper, we compare results from two different group vaccination events organized annually as part of the Dutch National Immunisation Programme, where the social robot was deployed to inform the children about the procedure by means of a short video developed by the Dutch Child and Family Center (CJG). Our study is a part of a 5-year research project, where we plan to study different robot behaviors in different healthcare settings. As a baseline for this project, we deployed a robot without gestures during the annual group vaccination day. The year thereafter, we have added emotional gestures to the interaction with the goal to compare the two robot interventions in terms of their effect on engagement, anxiety, fear, and trust in this particular context. Ethical approval was obtained from the ethics board of our university.

3.1 Creation of Emotional Gestures

For the emotional gestures condition, we used gestures with high levels of arousal to increase levels of distraction [49] and positive valence to match the high-pitched voice and joyful music in the video as well as positively influence the emotional state of the children [14], as positive emotions lead to higher engagement [56]. The robot carried out five universally understood gestures in the following order: 1. Arms stretched out and hands pointing to the front following the 4-key frame steps from [18], 2. Robot cheers to the side [19], 3. Robot cheers to the front [43], 4. Arms stretched out with hands pointing to the front [18], 5. Robot is dancing [44]. Each gesture was executed once. Both at the beginning and at the end of the interaction, the robot waved its arm while saying hello / goodbye. Since the robot was placed at the end of the queue and many children attended the vaccination day, it could happen that multiple children would interact with the robot at the same time. Gaze behavior of the robot was therefore kept neutral, but matched to the executed gestures (e.g. when stretching out the hands in front and up, the robot's head would follow). See our *Supplementary materials* for a video of the used gestures.

3.2 Pilot Study

To test the study set up and evaluate the gestures created, a pilot study was carried out during a group vaccination day in March for older children. The main focus was to have a first exploration of the experimental set-up and detect potential pitfalls with the goal to define improvements for the final study. In this pilot study, every child interacted with a robot expressing emotional gestures. The sample consisted of 40 participants (22 boys, 16 girls) with age range between 9 and 17 years old (M_{age} = 11.39, SD_{age} = 2.20). Due to this wider age range, assumptions for the final study should be taken with care given the target age group is 9 year old's who may perceive robots differently. From the 40 participants, there were only 10 participants that could be used for the observed engagement as in other cases they were obscured, or the robot interaction was not correctly attended (e.g., technical problems with the robot or incorrectly executed gestures). We observed that children would often stand on a green dot on the floor to interact with the robot. Yet this dot was part of the environment and not a deliberate choice for the experiment. We moved the robot slightly to prevent this behavior. Some parents forgot to sign the consent form. We printed the signature lines on the first page to ensure consent was given, while questions appeared on the next page. Based on the pilot study and subsequent exploration of the data, we adjusted the layout of the survey for clarity, discussed congruence of the coding scheme, and integrated appropriate emotional and semantical gestures in the robot interaction.

3.3 Participants, Research Setting & Research Team

This research was carried out the annual group vaccination days organized by the Dutch Child and Family Center (CJG) in Capelle aan de IJssel, the Netherlands. The CJG provides general healthcare to children and their families, such as vaccines, eye tests and check-ups, but also family coaching and mental support when needed. For the two group vaccination days, children aged 9 years old living in the area are invited to come by and receive the advised vaccinations according to the Dutch National Immunisation Programme. For the first study, three researchers were present. Their tasks were to inform the children and their guardians, turn on the robot, and collect the questionnaires. At the second study, six researchers were present, to account for an additional robot that was placed near the exit. Participants were recruited at the entrance of the vaccination location by means of voluntary sampling after informing the children and adult guardians about the study.

For the baseline condition of our study in which a total of 149 children participated, we deployed a robot without gestures during the annual group vaccination day on March 9, 2021. During the annual event a year later on April 19, 2022 in which a total of 129 children participated, we deployed the same robot but this time the robot was programmed to show emotional gestures. Due to the layout of the vaccination location, it was impossible to study both conditions at the same time.

Not all participants completed the questionnaire, and –due to the layout of the vaccination day during the baseline study– not all participants were able to see the robot while waiting for their vaccination. The final data sample therefore consists of 249 participants (120 boys, 89 girls, and 40 gender unknown) ranging from 8 to 10 years old (M_{age} = 8.34, SD_{age} = 0.49).

3.4 Procedure

A schematic overview of the procedure is presented in Figure 2. Positioning of the robot in the environment can be seen in Figure 1. First, the children enter the vaccination location together with their guardians. On arrival they were welcomed by one or two researchers, who informed them about the study and asked if they were interested in participating. Participants were handed out a questionnaire on paper, and the guardians were asked to sign an informed consent form. The child was instructed to complete the first part of the questionnaire while awaiting further instructions. The child was allowed to complete the questionnaire together with their guardian. The questionnaire asked for some demographics and a question to assess the current state of anxiety. After completing the first part of the questionnaire, the participants were instructed to continue in the queue for registration (visible in Figure 2, step 3) for the vaccination. This is where the first interaction with the robot took place with the robot displaying a short information video about vaccinations. In the baseline condition, the robot would only display the video on its tablet mounted on its front, while the robot in the emotional gestures condition executed emotional gestures alongside the video. The interaction was recorded with a video camera for analysis. After the video had ended (optimally, because the child could leave at any point during the interaction) the child continued queuing for the registration and following vaccination. After the administration of the vaccine, participants moved towards to the exit. Here, they were asked to complete the second part of the questionnaire. For the baseline condition, this was the end of the session, and participants were asked to hand in their questionnaire and thanked for their participation.

The emotional gestures condition featured a second interaction with the robot. At the exit, after handing in their questionnaires, the children were asked whether they wanted to have a second and final interaction with the robot. The questionnaire was then put into one of the two mailboxes, depending on whether the child wanted to have a second interaction with the robot (step 5 in Figure 2). The robot asked two questions during this second interaction: "How was your vaccination experience?" and "What are you going to do next?". The first question was chosen to evaluate the child's vaccination experience, while the second question was chosen to replicate a natural conversation between the robot and the child, including small talk. Dutch people commonly end conversations asking for other people's plans for the day. With this question, we also gave the children the opportunity to share something from their daily life with the robot. The participant could verbally respond to these questions. After the interaction ended, participants could follow their way to the exit.

3.5 Materials

For both studies, two iPal robots were used, as well as two cellphones to control the robots by means of the iRemoter application. Two consumer grade video cameras were present to record the interactions. During the second interaction in the emotional gestures condition, a lavalier clip-on microphone taped to the head of the robot was used to record the responses of the children. A short video (1:17 minutes long) designed by the CJG, informing the children about the vaccination procedure, was played on the robot. See our *Supplementary materials* for the video including the robot gestures used.

3.6 Measurements & Data Analysis

3.6.1 Self-reported Engagement, Anxiety, Fear and Trust. For all self-report questions in the questionnaire, a 5-point Likert scale from 1 (Surely not) to 5 (Yes, very much) was used, with corresponding smileys, as this is methodologically advised for self-report with children [40]. Low values indicate a low score on the corresponding concept (i.e., engagement, anxiety, fear, and trust), while high values indicate a high score on the corresponding concept.

Engagement, Fear, and Trust were measured based on a questionnaire developed by Looije et al. [30]. To measure engagement, we asked whether they would like to use the robot again, indicating a possible future interaction which might indicate long-term engagement, as well as whether they wanted to see a video on the robot again. To measure fear, we asked pre- and post-vaccination how they felt about getting a vaccine. To measure trust, we asked whether they would tell a secret to the robot. Additionally, *Anxiety*, which is a time restricted state and a subordinate emotion of fear [42], was measured with a question from the Modified Short State-Trait Anxiety Inventory for children [38]: "In this moment - I feel calm". This question in turn is adapted from the original State-Trait Anxiety Inventory for Children State [46] and uses facial expressions to symbolise emotions.

3.6.2 Observed Engagement. All video data was qualitatively and quantitatively analyzed. We used a video coding approach in line

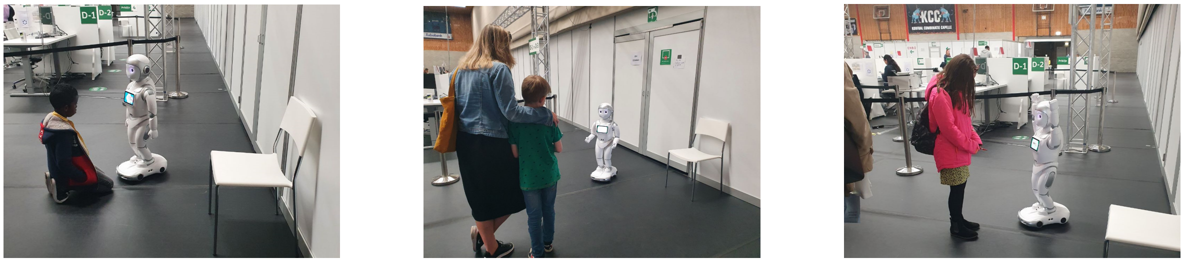


Figure 1: Pictures of the research set-up

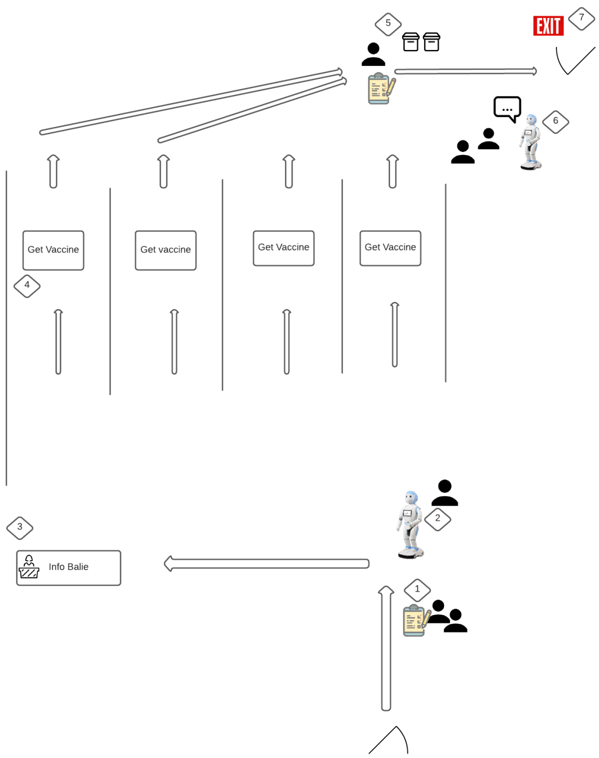


Figure 2: Map of research location and study procedure. N.B. 6 only took place in the emotional gestures condition

Table 1: Engagement coding scheme

Value	Evaluation	Observation
1	Intense noncompliance	Participant walks away from the area where the interaction takes place
2	Noncompliance	Negative utterances: Participant looks around, or hangs head and is interested in different things, Signs of boredom
3	Neutral	Participant is gazing towards robot and follows video
4	Slight Engagement	Positive utterances: participant walks towards the robot or close stand Smiles of participant, slight attempts to interact
5	Intense Engagement	Mimicking of robot , excitable bouncing, strong attempts to interact, Concentration signs, Laughing of participant

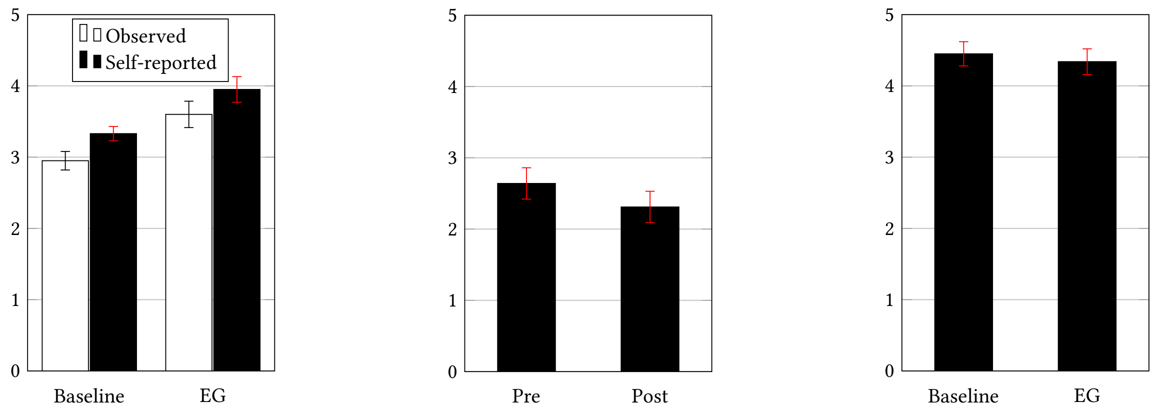
with previous research in the field of CRI [25, 30] and video materials were independently coded by two researchers using the coding scheme (see Table 1). Each video was divided into 5 seconds slots, and a primary coder assigned a code to each slot. Frame slots in which the participant was not visible in the frame slot (e.g., because they were standing too far away from the robot or they were occluded by parents or fellow participants) were annotated as missing with code '0'. If more than 30% of the slots for a particular participant were annotated as missing, the data of that participant was not included in the final data analysis. For the remaining participants, the missing frame slots were replaced with the median per participant. This preprocessing resulted in a total number of 40 participants in the no gestures condition (baseline) and 71 for the emotional gestures condition.

In total, 30% of the video data was randomly selected and the same procedure of applying codes was performed by a second coder, which was deemed sufficient for generalization given a moderately large dataset (e.g., [28, 33]). Disagreements were discussed and resolved between the two annotators, after which inter-coder reliability [39] was calculated. This resulted in an overall good agreement for first interaction in the emotional gestures condition ($\alpha = .816$), a moderate agreement for no gesture (baseline) condition ($\alpha = .642$), and an almost very good reliability for the second interaction in the emotional gestures condition ($\alpha = .896$). Given these values, it can be assumed that the codes are in accordance and can be used for further data analysis.

3.6.3 Vaccination Experience & Sentiment Analysis. Qualitatively it was assessed how the child perceived the vaccination. For that, a short interview was held by the robot itself. The answers of the children were transcribed verbatim and assessed. Given the relevance of the child's affective state for measuring engagement, the sentiment of the child's answers were coded by two researchers (positive, negative, and neutral) and, after checking for inter-coder reliability a good agreement was reached ($\alpha = 0.928$). This data was then analyzed along with the other collected data. Additionally, engagement was measured by using the developed coding scheme, see Table 1, by two researchers ($\alpha = 0.896$).

4 RESULTS

An overview of the findings of the two studies are presented in Table 2, including results on sample size, means and standard deviations of the collected variables, for each condition separately (baseline condition, and the emotional gestures condition) as well as for the complete data sample.



(a) Mean Self-reported and Observed Engagement for both conditions (baseline and emotional gestures (EG))

(b) Mean Pre- and Post-Anxiety for the emotional gestures condition

(c) Mean Trust for both conditions (baseline and emotional gestures (EG))

Figure 3: Results

Table 2: Overview of N, Mean and SD per condition.

	Baseline			Emotional Gestures			Total		
	N	M	SD	N	M	SD	N	M	SD
Observed Engagement	40	2.95	0.43	71	3.33	0.45	111	3.19	0.48
Self-reported Engagement	126	3.60	1.06	94	3.95	0.88	220	3.75	1.00
Pre-Anxiety				100	2.64	1.15			
Post-Anxiety				94	2.31	1.08			
Pre-Fear	124	3.16	1.13	100	3.22	1.07	225	3.19	1.10
Post-Fear	119	3.19	1.18	95	3.36	1.10	215	3.27	1.14
Trust	122	4.45	0.96	83	4.34	0.83	205	4.40	0.91

4.1 Engagement

An initial analysis investigated a potential association between self-reported and observed engagement. A Spearman correlation was insignificant (r = 0.04, $p = 0.366$), interestingly failing to detect such an association.

4.1.1 Observed Engagement. To investigate the effect of emotional gestures on observed engagement, we compared the data from the two studies. We found a significant difference (Mann-Whitney $U = 781.00$, $N_1 = 40$, $N_2 = 71$, $p < 0.001$), showing that children were more engaged when interacting with a robot using emotional gestures ($M = 3.33$, $SD = 0.45$) compared to a robot using no gestures ($M = 2.95$, $SD = 0.43$).

4.1.2 Self-Reported Engagement. A similar effect for using emotional gestures was found for self-reported engagement (Mann-Whitney $U = 4836.00$, $N_1 = 126$, $N_2 = 94$, $p = 0.009$). Children reported a higher level of engagement when interacting with a robot using gestures ($M = 3.89$, $SD = 0.92$) compared to children interacting with a robot using no gestures ($M = 3.60$, $SD = 1.06$).

4.2 Anxiety

Anxiety was measured both before as well as after vaccination, but only in the emotional gestures condition. A Wilcoxon test showed a significant difference between pre- and post state anxiety ($z = -1.805$, $p = .035$), indicating that the children's anxiety decreased after the intervention ($M = 2.31$) compared to their anxiety before the intervention ($M = 2.64$).

To investigate whether this decrease in anxiety may be caused by the engagement levels resulting from the robot using emotional gestures , we ran four separate Spearman correlations. We found no significant associations between observed or self-reported engagement and anxiety before nor after the CRI.

4.3 Fear

To investigate the effect of emotional gestures on fear both before and after the intervention, we compared the data from the two studies. A Friedman test showed no differences in pre- and post-fear between the no gestures and emotional gestures conditions ($X^2(3) = 1.762$, $p = 0.623$).

To investigate whether any difference for fear may be caused by the engagement levels resulting from the robot using emotional gestures, we ran four separate Spearman correlations. Spearman correlations show no relationships between observed as well as self-reported engagement and fear, before as well as after the CRI.

4.4 Trust

To investigate the effect of emotional gestures on trust, we compared the data from the two studies. We found a significant difference (Mann-Whitney $U = 4450.50$, $N_1 = 122$, $N_2 = 83$, $p = 0.045$), showing that children had lower trust in the robot using emotional gestures (M = 4.34, SD = 0.83) compared to a robot without gestures (M = 4.45, SD = 0.96).

To investigate whether this decrease in trust may be caused by the engagement levels resulting from the robot using emotional gestures, we ran two separate Spearman correlations. We found that trust was associated with self-reported engagement (r(201) = .26, p =< .001) but not with observed engagement (r(59) = .10, p = .236).

4.5 Self-Disclosure and Engagement

To explore the effect of emotional gestures on self-disclosure, we deployed a second robot at the exit during the second study to ask the children about their vaccination experience and plans for the day after the questionnaire was handed in. Word count is used to indicate the richness of the engagement as well as breadth of the child's self-disclosure, while a sentiment analysis was carried out to explore the depth of self-disclosure.

4.5.1 Word Count. On average, the word count was 7.37 words per participant (N = 77). The average word count of the first answer was 2.57, and of the second answer 4.16 words. We found a nearing significant correlation between word count and observed engagement (r(55) = .20, p = 0.070) or self-reported engagement(r(68) = .17, p = 0.083), pointing at a potential trend in the data that shows a richer interaction may be associated with both higher observed and self-reported engagement.

4.5.2 Sentiments. The overall sentiments expressed while answering the first question ("How was your vaccination experience?") are more negative (46 negative statements, 6 neutral, and 24 positive statements), as it was expected regarding the relatively higher levels of fear and anxiety. Children provided rather short answers to this question, mainly describing the state of the child (e.g., "tensive", "fun", "not fun", "scary"), as can be seen in Figure 4a. Answers to the second question ("What are you going to do next?") were similar amongst the children (e.g., "going back to school", "going home") and mostly lacked any further emotional information (1 negative statement, 76 neutral statements), as can be seen in Figure 4b.

(a) Vaccination experience. (b) Next activity.

Figure 4: Word clouds of child's statements to the robot.

4.5.3 Observed Engagement. The observed engagement of the second interaction at the exit is positively associated with the word count (r(73) = .36, p =< .001), marginally significant in association with the observed engagement during the first interaction (r(68) = .20, p = .058), and positively correlated with self-reported engagement during the first interaction (r(80) = .24, p =< .016). Additionally, a positively correlation was found between observed engagement during the second interaction and self-reported fear before the intervention (r(80) = .18, p = .049), indicating that children with higher fear before vaccination were less engaged during the second interaction.

4.6 Other observations

To evaluate the success of our robot intervention, we checked whether the children understood the robot (M = 4.2, SD = 0.70) and the video (M = 4, SD = 0.87) in the no gestures condition (N = 125). These high average scores showed positive indications of them understanding the information presented. While running the baseline study, we noticed that more anxious children seemed less willing to participate. To further explore this, we counted the willingness of the children to participate during the second study and whether they were anxious. We collected such data for 60 children, of which 27 indicated to be not anxious and willing to participate, 14 to be not anxious but not willing to participate, 11 that were anxious and not willing to participate, and 8 that were anxious but willing to participate. A chi-square test showed a potential trend in the relationship between anxiety and willingness to participate ($\chi^2(1) = 3.0127$, p = .083).

During the interactions, some anecdotal observations were that children seemed to almost only gaze at the video screen when the robot used no gestures. In the gesture condition, children seemed to follow the robot's movements and gaze at its face. When the robot moved its arms, the children seemed to smile or get excited, potentially indicating direct effects of gestures on the child. Also, the willingness for interacting with the robot seemed higher after receiving the vaccine. Here, also children that did not consent for participating in the study before receiving the vaccine, asked to talk to the robot. These children were not recorded and therefore excluded from analysis.

5 GENERAL DISCUSSION

Socially assistive robots (SARs) show potential in reducing stress in children before receiving medical treatment, such as vaccinations. However, it remains unclear which behaviors SARs should express for a successful intervention, especially for child-robot interaction (CRI). The aim of our research was therefore to investigate the effects of emotional gestures during CRI on engagement, anxiety, fear, and trust by running a real-world experiment during two annual group vaccination days in the Netherlands.

Our findings indicate that emotional gestures, rather than no gestures, in a CRI results in higher observed as well as self-reported engagement. These findings substantiates previous research showing that emotional gestures guide attention [12], assuming that emotional gestures are attracting the visual attention and increasing human-likeness resulting in higher engagement and subsequently fulfilling children expectations about robots. Especially in a distracting environment such as the one described in this paper, robot interactions need to be engaging [24]. Anecdotal observations indicate that children follow the movements of robot's arms and try to mimic them, confirming that gestures catch attention. Even though emotional gestures increased ratings of both self-reported and observed engagement, the two measures of engagement did not significantly correlate. This means that children who had a high self-reported engagement were not necessarily observed as being highly engaged during the interaction, emphasizing the importance of distinguishing between observed and self-reported engagement.

Moreover, children's state anxiety was significantly higher before the vaccination and interaction with the robot compared to measures collected afterwards. The lower state anxiety after interaction might be caused by higher levels of observed engagement with robots using gestures; an observation that needs further exploration in future research. However, our results show no effect of emotional gestures on self-reported fear. Moreover, we found no effect of a social robot present at a vaccination day on self-reported fear in general. Additionally, no effects of fear and anxiety on child's engagement were found. However, we observed that more anxious children seemed to be less willing to participate. This could have led to a bias, not being able to include higher levels of fear and anxiety in our comparisons, since they were less present in our data sample.

Interestingly, self-reported trust was lower for robots using emotional gestures compared to the no gestures condition. This is especially surprising given that gestures such as open arms are considered to evoke trust and credibility in people [52]. Additionally, our results indicate that higher levels of trust corresponded with higher levels of self-reported engagement. It could be that the used gestures were too hectic, as joyful gestures are usually executed at a higher speed. This could have distracted participants from the informative video. Gaze is an important indication of trust, with averted gaze lowering the level of perceived trust [54]. The robot averting his gaze more often in the emotional gestures condition could therefore have led to lower levels of child's trust.

5.1 Limitations

Since this study is a real-world study, we encountered some technical challenges. Due to participants positioning themselves out of the video frame or parents obscuring the view, there were many missing slots for the observed engagement. Consequently, the number of participants here is quite low, especially in the no gesture condition. A larger code-able sample size may have resulted in more significant results. Additionally, because of the set-up of the vaccination day, it was impossible to thoroughly control the questionnaires being fully completed and at the right time of the procedure. This led to multiple missing values. Due to the location of the vaccination day (i.e. a big open space, with children walking in and out throughout the whole day), we could not prevent children encountering only one of the two conditions. Therefore, we had two collect our data in two different subsequent years, namely the baseline study in the first year, and the emotional gestures condition in the second year. We decided to collect a baseline database in 2021, which we could compare with future studies in the subsequent years for our research project. Since children only receive the corresponding vaccinations once in their life, double participation was not possible.

From observations and informal conversations on-site, parents and medical staff seemed in general very positive about the robot application. Including them systematically was not feasible during this large event but we have included opinions of parents and child healthcare practitioners in other research (e.g., [35–37]).

5.2 Future Research

Future research should further explore the effects of different robot features and behaviors, also beyond emotional gestures, on children's engagement. By comparing specific behaviors to our baseline study, we were able to investigate the effects of these behaviors on relevant interaction factors such as engagement and stress reduction. Additionally, looking into participant-specific traits, such as a child's personality, could lead to interesting results. For example, extroverted children tend to prefer extroverted robots [2]. Adapting robot behavior to the child's personality might increase the effectiveness of the SARs intervention by tailoring the interaction to the preferences of the child.

After the vaccination, children in the emotional gestures group were asked to share their vaccination experience with the robot. The children answered the first question ("How was your vaccination experience?") with more (mostly negative) sentiment, compared to the second one ("What are you going to do next?"), even though they used more words when responding to the second question. However, the children did not state anything about how they experienced their interactions with the robot while waiting. For future research, it would be interesting to ask the children this directly, to gain more insights in the perceived value of having the robot there.

6 CONCLUSION

This real-world study investigates the effects of using emotional gestures in a socially assistive robot at an annual group vaccination day. The robot was placed in the waiting area where children were waiting before receiving their vaccination. The aim of this study was to see whether a child-robot interaction (CRI) before the vaccination would reduce stress levels in children.

Our results show a positive effect of adding emotional gestures to a SAR's interactive behavior during a group vaccination day. Children were more engaged and experienced lower anxiety in the waiting area when the robot used emotional gestures. Additionally, children who self-reported to be more engaged with the robot also showed higher trust in the robot. Moreover, in a distracting environment, emotional gestures may be able to capture children's attention better by providing a more engaging interaction. Thus, adding emotional gestures during a CRI is a powerful way to improve the child's experience during a group vaccination day.

ACKNOWLEDGMENTS

We would like to thank all children and parents for their participation, as well as Andrew Kambel, Jesse Hoekman, Thomas Dallmeir, Rosalie Wendt, and Jesse Borghardt for supporting us during the vaccination day. This research was supported by the Flemish Research Foundation grant no. 1S95020N.

REFERENCES

[1] Muneeb Imtiaz Ahmad, Omar Mubin, Suleman Shahid, and Joanne Orlando. 2019. Robot's adaptive emotional feedback sustains children's social engagement and promotes their vocabulary learning: a long-term child–robot interaction study. *Adaptive Behavior* 27, 4 (2019), 243–266.

[2] Amir Aly and Adriana Tapus. 2013. A model for synthesizing a combined verbal and nonverbal behavior based on personality traits in human-robot interaction. In *2013 8th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 325–332.

[3] Salvatore M Anzalone, Sofiane Boucenna, Serena Ivaldi, and Mohamed Chetouani. 2015. Evaluating the engagement with social robots. *International Journal of Social Robotics* 7, 4 (2015), 465–478.

[4] Giulia Belgiovine, Jonas Gonzalez-Billandon, Giulio Sandini, Francesco Rea, and Alessandra Sciutti. 2022. Towards an HRI Tutoring Framework for Long-term Personalization and Real-time Adaptation. In *Adjunct Proceedings of the 30th ACM Conference on User Modeling, Adaptation and Personalization*. 139–145.

[5] Tony Belpaeme, Paul Baxter, Robin Read, Rachel Wood, Heriberto Cuayáhuitl, Bernd Kiefer, Stefania Racioppa, Ivana Kruijff-Korbayová, Georgios Athanasopoulos, Valentin Enescu, et al. 2012. Multimodal child-robot interaction: Building social bonds. *Journal of Human-Robot Interaction* 1, 2 (2012).

[6] Tanya N Beran, Alex Ramirez-Serrano, Otto G Vanderkooi, and Susan Kuhn. 2013. Reducing children's pain and distress towards flu vaccinations: a novel and effective application of humanoid robotics. *Vaccine* 31, 25 (2013), 2772–2777.

[7] Tanya N Beran, Alex Ramirez-Serrano, Otto G Vanderkooi, and Susan Kuhn. 2015. Humanoid robotics in health care: An exploration of children's and parents' emotional reactions. *Journal of health psychology* 20, 7 (2015), 984–989.

[8] E Bevacqua, M Mancini, and C Pelachaud. 2004. Speaking with emotions. In *Proceedings of the AISB Symposium on Motion, Emotion and Cognition*. 197–214.

[9] Marie-Luce Bourguet, Yanning Jin, Yuyuan Shi, Yin Chen, Liz Rincon-Ardila, and Gentiane Venture. 2020. Social Robots that can Sense and Improve Student Engagement. In *2020 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*. 127–134. https://doi.org/10.1109/TALE48869.2020.9368438

[10] Cynthia Breazeal. 2004. *Designing sociable robots*. MIT press.

[11] Cynthia Breazeal. 2004. Social interactions in HRI: the robot view. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)* 34, 2 (2004), 181–186.

[12] Thierry Chaminade, Massimiliano Zecca, Sarah-Jayne Blakemore, Atsuo Takanishi, Chris D Frith, Silvestro Micera, Paolo Dario, Giacomo Rizzolatti, Vittorio Gallese, and Maria Alessandra Umiltà. 2010. Brain response to a humanoid robot in areas implicated in the perception of human emotional gestures. *PLoS one* 5, 7 (2010), e11577.

[13] Nele Dael, Martijn Goudbeek, and Klaus R Scherer. 2013. Perceived gesture dynamics in nonverbal expression of emotion. *Perception* 42, 6 (2013), 642–657.

[14] Oana A David and Daniel David. 2022. How can we Best Use Technology to Teach Children to Regulate Emotions? Efficacy of the Cognitive Reappraisal Strategy Based on Robot Versus Cartoons Versus Written Statements in Regulating Test Anxiety. *Journal of Rational-Emotive & Cognitive-Behavior Therapy* (2022), 1–10.

[15] Julia Dawe, Craig Sutherland, Alex Barco, and Elizabeth Broadbent. 2019. Can social robots help children in healthcare contexts? A scoping review. *BMJ paediatrics open* 3, 1 (2019).

[16] David Feil-Seifer and Maja J Mataric. 2005. Defining socially assistive robotics. In *9th International Conference on Rehabilitation Robotics, 2005. ICORR 2005.* IEEE, 465–468.

[17] Susan Fowler-Kerry and Janice Ramsay Lander. 1987. Management of injection pain in children. *Pain* 30, 2 (1987), 169–175.

[18] Donald Glowinski, Antonio Camurri, Gualtiero Volpe, Nele Dael, and Klaus Scherer. 2008. Technique for automatic emotion recognition by body gesture analysis. In *2008 IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops*. IEEE, 1–6.

[19] Jillian Greczek, Katelyn Swift-Spong, and Maja Matarić. 2011. *Using eye shape to improve affect recognition on a humanoid robot with limited expression*. Technical Report. Technical report.

[20] Joanna Hall, Terry Tritton, Angela Rowe, Anthony Pipe, Chris Melhuish, and Ute Leonards. 2014. Perception of own and robot engagement in human–robot interactions and their dependence on robotics knowledge. *Robotics and Autonomous Systems* 62, 3 (2014), 392–399.

[21] Olivier A Blanson Henkemans, Bert PB Bierman, Joris Janssen, Mark A Neerincx, Rosemarijn Looije, Hanneke van der Bosch, and Jeanine AM van der Giessen. 2013. Using a robot to personalise health education for children with diabetes type 1: A pilot study. *Patient education and counseling* 92, 2 (2013), 174–181.

[22] Robert M Jacobson, Avril Swan, Adedunni Adegbenro, Sarah L Ludington, Peter C Wollan, Gregory A Poland, Vaccine Research Group, et al. 2001. Making vaccines more acceptable—methods to prevent and minimize pain and other common adverse events associated with vaccines. *Vaccine* 19, 17-19 (2001), 2418–2427.

[23] Lindsay A Jibb, Kathryn A Birnie, Paul C Nathan, Tanya N Beran, Vanessa Hum, J Charles Victor, and Jennifer N Stinson. 2018. Using the MEDiPORT humanoid robot to reduce procedural pain and distress in children with cancer: a pilot randomized controlled trial. *Pediatric blood & cancer* 65, 9 (2018), e27242.

[24] Daniel Kahneman. 1973. *Attention and effort*. Vol. 1063. Citeseer.

[25] Elizabeth Kim, Rhea Paul, Frederick Shic, and Brian Scassellati. 2012. Bridging the research gap: Making HRI useful to individuals with autism. (2012).

[26] Stefan Kopp, Kirsten Bergmann, and Ipke Wachsmuth. 2008. Multimodal communication from multimodal thinking—towards an integrated model of speech and gesture production. *International Journal of Semantic Computing* 2, 01 (2008), 115–136.

[27] Tryphena T Lewis, Hyunji Kim, Ashley Darcy-Mahoney, Mia Waldron, Won Hyong Lee, and Chung Hyuk Park. 2021. Robotic uses in pediatric care: A comprehensive review. *Journal of Pediatric Nursing* 58 (2021), 65–75.

[28] Jennifer Pals Lilgendahl and Dan P McAdams. 2011. Constructing stories of self-growth: How individual differences in patterns of autobiographical reasoning relate to well-being in midlife. *Journal of personality* 79, 2 (2011), 391–428.

[29] Phoebe Liu, Dylan F Glas, Takayuki Kanda, and Hiroshi Ishiguro. 2016. Data-driven HRI: Learning social behaviors by example from human–human interaction. *IEEE Transactions on Robotics* 32, 4 (2016), 988–1008.

[30] Rosemarijn Looije, Mark A Neerincx, and Vincent de Lange. 2008. Children's responses and opinion on three bots that motivate, educate and play. (2008).

[31] Jill E MacLaren and Lindsey L Cohen. 2005. A comparison of distraction strategies for venipuncture distress in children. *Journal of Pediatric Psychology* 30, 5 (2005), 387–396.

[32] Chris McCarthy, Jo Butchart, Michael George, Dee Kerr, Hugh Kingsley, Adam M Scheinberg, and Leon Sterling. 2015. Robots in rehab: towards socially assistive robots for paediatric rehabilitation. In *Proceedings of the annual meeting of the australian special interest group for computer human interaction*. 39–43.

[33] Kate C McLean and Michael W Pratt. 2006. Life's little (and big) lessons: identity statuses and meaning-making in the turning point narratives of emerging adults. *Developmental psychology* 42, 4 (2006), 714.

[34] Jauwairia Nasir, Barbara Bruno, Mohamed Chetouani, and Pierre Dillenbourg. 2021. What if Social Robots Look for Productive Engagement? *International Journal of Social Robotics* (2021), 1–17.

[35] Anouk Neerincx, Thirza Hiwat, and Maartje De Graaf. 2021. Social Robot for Health Check and Entertainment in Waiting Room: Child's Engagement and Parent's Involvement. In *Adjunct Proceedings of the 29th ACM Conference on User Modeling, Adaptation and Personalization*. 120–125.

[36] Anouk Neerincx and Amy Luijk. 2020. Social Robot's Processing of Context-Sensitive Emotions in Child Care: A Dutch Use Case. In *Companion Publication of the 2020 International Conference on Multimodal Interaction*. 503–505.

[37] Anouk Neerincx, Denise L Rodenburg, Maartje MA de Graaf, and Judith FM Masthoff. 2021. Social Robots to Support Child and Family Care: A Dutch Use Case. In *Companion of the 2021 ACM/IEEE International Conference on Human-Robot Interaction*. 367–371.

[38] Stefan Nilsson, Margret Buchholz, and Gunilla Thunberg. 2012. Assessing children's anxiety using the modified short state-trait anxiety inventory and talking mats: A pilot study. *Nursing Research and Practice* 2012 (2012).

[39] Cliodhna O'Connor and Helene Joffe. 2020. Intercoder reliability in qualitative research: debates and practical guidelines. *International journal of qualitative methods* 19 (2020), 1609406919899220.

[40] Janet C Read, Stuart MacFarlane, and Chris Casey. 2002. Endurability, engagement and expectations: Measuring children's fun. In *Interaction design and children*, Vol. 2. Shaker Publishing Eindhoven, 1–23.

[41] Silvia Rossi, Marwa Larafa, and Martina Ruocco. 2020. Emotional and behavioural distraction by a social robot for children anxiety reduction during vaccination. *International Journal of Social Robotics* 12, 3 (2020), 765–777.

[42] James A Russell and Lisa Feldman Barrett. 1999. Core affect, prototypical emotional episodes, and other things called emotion: dissecting the elephant. *Journal of personality and social psychology* 76, 5 (1999), 805.

[43] Richard Savery, Lisa Zahray, and Gil Weinberg. 2021. Emotional musical prosody for the enhancement of trust: Audio design for robotic arm communication. *Paladyn, Journal of Behavioral Robotics* 12, 1 (2021), 454–467.

[44] Mohammad Shidujaman, Shenghua Zhang, Robert Elder, and Haipeng Mi. 2018. "roboquin": A mannequin robot with natural humanoid movements. In *2018 27th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 1051–1056.

[45] Candace L Sidner, Christopher Lee, Cory D Kidd, Neal Lesh, and Charles Rich. 2005. Explorations in engagement for humans and robots. *Artificial Intelligence* 166, 1-2 (2005), 140–164.

[46] Charles Donald Spielberger. 1970. Manual for the state-trait anxietry, inventory. *Consulting Psychologist* (1970).

[47] Caroline L van Straten, Jochen Peter, Rinaldo Kühne, and Alex Barco. 2020. Transparency about a robot's lack of human psychological capacities: Effects on child-robot perception and relationship formation. *ACM Transactions on Human-Robot Interaction (THRI)* 9, 2 (2020), 1–22.

[48] Daniel Szafir and Bilge Mutlu. 2012. Pay attention! Designing adaptive agents that monitor and improve user engagement. In *Proceedings of the SIGCHI conference on human factors in computing systems*. 11–20.

[49] Joseph J Tecce, June Savignano-Bowman, and Debbie Meinbresse. 1976. Contingent negative variation and the distraction—arousal hypothesis. *Electroencephalography and clinical neurophysiology* 41, 3 (1976), 277–286.

[50] Myrthe Tielman, Mark Neerincx, John-Jules Meyer, and Rosemarijn Looije. 2014. Adaptive emotional expression in robot-child interaction. In *2014 9th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 407–414.

[51] Gentiane Venture and Dana Kulić. 2019. Robot expressive motions: a survey of generation and evaluation methods. *ACM Transactions on Human-Robot Interaction (THRI)* 8, 4 (2019), 1–17.

[52] Kasia Wezowski and Patryk Wezowski. 2018. *Without Saying a Word: Master the Science of Body Language and Maximize Your Success*. AMACOM.

[53] Katie Winkle, Praminda Caleb-Solly, Ailie Turton, and Paul Bremner. 2018. Social robots for engagement in rehabilitative therapies: Design implications from a study with therapists. In *2018 13th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 289–297.

[54] Carrie L Wyland and Joseph P Forgas. 2010. Here's looking at you kid: Mood effects on processing eye gaze as a heuristic cue. *Social Cognition* 28, 1 (2010), 133.

[55] Junchao Xu, Joost Broekens, Koen Hindriks, and Mark A Neerincx. 2015. Mood contagion of robot body language in human robot interaction. *Autonomous Agents and Multi-Agent Systems* 29, 6 (2015), 1216–1248.

[56] Xiao-Yu Xu, Wen-Bo Niu, Qing-Dan Jia, Lebogang Nthoiwa, and Li-Wei Li. 2021. Why Do Viewers Engage in Video Game Streaming? The Perspective of Cognitive Emotion Theory and the Moderation Effect of Personal Characteristics. *Sustainability* 13, 21 (2021), 11990.

[57] Sang-Seok Yun, JongSuk Choi, Sung-Kee Park, Gui-Young Bong, and HeeJeong Yoo. 2017. Social skills training for children with autism spectrum disorder using a robotic behavioral intervention system. *Autism Research* 10, 7 (2017), 1306–1323.

[58] Paulina Zguda, Anna Kołota, Mateusz Jarosz, Filip Sondej, Takamune Izui, Maria Dziok, Anna Belowska, Wojciech Jędras, Gentiane Venture, Bartłomiej Śnieżynski, et al. 2019. On the role of trust in child-robot interaction. In *2019 28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 1–6.