Design and Perception of a Social Robot to Promote Hand Washing among Children in a Rural Indian School

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***Abstract*— We introduce "Pepe", a social robot for encouraging proper handwashing behaviour among children. We discuss the motivation, the robot design and a pilot study conducted at a primary school located in the Western Ghats mountain ranges of Southern India with a significant presence of indigenous tribes. The study included individual & group interviews with a randomly selected sample of 45 children to gauge their perception of the Pepe robot across various dimensions including gender, animacy & technology acceptance. We also discuss some HRI implications for running user studies with rural children.**

I. INTRODUCTION

The Global Burden of Disease study in 2016 found that in developing countries, unsafe WASH (Water, Sanitation & Hygiene) is the third largest contributor to the global burden of disease [1]. Poor hand hygiene results in nearly 300,000 deaths annually, with the majority of deaths being among children younger than 5 years old. Despite its potential, handwashing with soap is seldom practiced in low-income countries. Freeman et al. in their systematic review of handwashing practices across the world estimated that only 19% of people across the world washed their hands with soap after coming into contact with faeces, and presents evidence from literature showing how handwashing with soap lead to a 40% reduction in the risk of diarrhoea [2]. For India, the statistics is even more dismal at a 15% handwashing prevalence rate. Considering Indias low handwashing rates and the enormous humanitarian and economic costs of the disease burden, handwashing promotion efforts in the country are especially needed.

Human-Robot Interaction technologies are advancing at a rapid pace thanks to advances in robotics and artificial intelligence and are being increasingly used in a wide variety of educational [3] and social scenarios [4]. We believe social robots have great potential to serve a supportive role in the machinery of large scale health interventions as both active agents of behaviour change as well as objective assessors of various indicators of health and hygiene. However it is important to study the design and behaviour factors of the robot that can affect childrens' perception in the context of handwashing promotion.

*This work was supported by the Amrita Vishwa Vidyapeetham University Research Seed Grant Program.

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II. RELATED WORK

Handwashing interventions are most needed in resource-poor context of rural areas. Schools in particular are a good target for interventions, as Chandrashekhar et al. [5] observed that students in Nepalese rural schools have more exposure to intestinal parasite infestations than children in urban schools due to the lack of health education and sanitation infrastructure in schools. But if implemented alone, awareness campaigns have limited impact as seen in the UNICEF's Great Hand Wash Yatra (Journey) [6], which used various activities like games, posters and flyers as the intervention. Though the campaign increased handwashing knowledge, it had little effect on actual hand washing behaviour.

Handwashing interventions in schools are an effective way of reaching children and teaching them the habit of handwashing at a young age. An intervention study in two primary schools in rural Bangladesh showed that the proportion of handwashing after toilet use among students increased from 4% to 68% after introducing nudges. Nudges included brightly colored paths were painted from toilets to the handwashing station, and footprints and handprints were painted on the path and handwashing station [7].

Biran et al. [8] with the SuperAmma initiative takes another approach by showing how emotional drivers using triggers for disgust are an effective means for improving handwashing behaviour. However, there exists little evidence of long term maintenance of hand washing behaviour following handwashing interventions [9].

Particularly of interest in the design of robots for the persuading people to adopt better handwashing behaviour is the Hawthorne effect. This effect has been quantified by Srigley et al. [10] where hand wash events were counted and compared between the presence and lack of auditors for monitoring handwashing. The auditors were found to significantly increase hand washing behaviour.

In regards to HRI studies in developing countries, Deshmukh et al. [11] pioneered the use of studying HRI techniques as a means to understand robot and gender perception among rural populations. The authors observed that most of the participants viewed the social robot, in this case a utility robot for transporting water, to be useful for reducing their burden of carrying water over long distances. The participants perceived the gender of the robot as female in-spite of the robot having a male voice due to cultural influence. Whatever the intervention is, it needs to be attractive and engaging to its target users to determine its success.

Our research into the application of social robots for changing handwashing behaviour seeks to break ground in multiple arenas of inquiry, including the perception of social robots by a young rural tribal audience and in the use of persuasive robots for changing health & hygiene behaviour among young children.

III. Robot Design

We designed our own low cost (approx 100 USD) robotic platform robot "Pepe" (Fig. III) with minimal expressive capabilities that can cater to the needs specific to hand-washing.

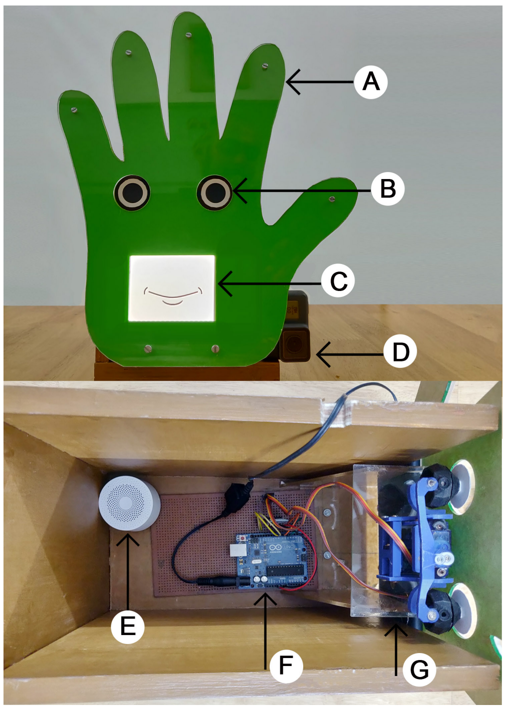

Fig. 1. Robot Design (Front View). A: Robotic Face (Acrylic), B: Eyes 2 DOF (yaw and pitch), C: Phone displaying robot's mouth, D: Front-facing camera, (Top View) E: Speaker, F: Micro controller, G: Eye Mechanism

A. Physical Appearance

According to Bartneck et al. [12] the shape, size, and material qualities of a social robot should match the task it is designed for to avoid false expectations. Hence a hand like shape was used in order to elicit a symbolic meaning specific to theme of the intervention (hand-washing). The colour of the robot was bright green which is known to depict good health, environment and goodwill. Acrylic was chosen as the material for the face as it is shiny and represents a clean surface closely tied to the theme of the intervention. Care was taken to design the robot contours to avoid sharp edges and to make the robot appear more friendly. The name "Pepe" was chosen after consultations with local residents and Malayalam language experts to decide on a name that was both appealing enough for the children to have easy recall, and unfamiliar enough that they do not ascribe any gender to the robot because of the name. It was initially inspired by a previous social robot named Pepe Jr [13].

B. Eye Design

Having movable eyes on the robot was especially important in this context, as people change their behaviour when they know they're being watched ("Hawthorne Effect") [14]. Also a field study by Pfattheicher et al. [15] showed a significant increase of hand hygiene compliance when watching eyes were presented in a restroom. The eye mechanism was 3D printed with PLA material from a design published under the creative commons [16] which has two degrees of freedom (in the yaw and pitch axes), with a range of -45 to +45 degrees in each axis. The mechanism is connected to an Arduino Uno microcontroller which sends PWM control signals to change the angles. We also designed the eyes of the robot to be round in shape with an iris with 75% coverage with respect to the whole eye region. This type of eye design seemed to convey a degree of friendliness according to Tomomi et al. [17]. The eyes movement could produce up-down, left-right movement as described in Table I.

C. Robot Speech

As there is lack of text-to-speech systems for Malayalam language (the local spoken language) we had a human (female) voice recording for all utterances required for this study. We shifted the pitch of the sounds files to resemble that of a child whose gender is not apparent in the voice. Child like voices are most effective in child-robot interaction studies so we incorporated that in our speech design [18]. We discuss the perceptions of the robot's gender among the children in the results section.

D. Control System

The remote control interface used by the wizard, and the robot controller (also acting as the robot's mouth) were both developed in Unity3D and ran on Android powered smart phones. The wizard could see live video feed from a room using two Go-Pro cameras one placed from the top to record hand movements and other was from the front of the robot to record/monitor interactions with the robot.

E. Robot behaviour

The robot was programmed to display expressions using the movement of the eyes (up-down or left-right) synchronised with the movement of the mouth and the pre-recorded audio. The mouth animation was a sequence of mouth positions played back at around 10 FPS. The same mouth movement was used for all verbal utterances from the robot. Table I shows the mapping between the children's behaviour and the robot's response/behaviour.

IV. Methodology

A. Study setting

The study was conducted in a government primary school in a village in the district of Wayanad in the state of Kerala,

		Robot Behaviour (WOZ)	
Activity	**Children's behaviour**	**Robot Speech**	**Eye Movement Pattern**
Approaching handwashing area	Post-toilet usage	Wash hand after toilet	right-left: 2.5s
	Approach before meals	Wash hand before meal	right-left: 2.5s
	When students come near the sink	Did you wash your hands today?	right-left: 2.5s
During handwashing	During initial training/proper hand washing	Counts from step 1 to 7	right: 0.2s left: 0.2s
	In the middle of hand washing steps	Clean between fingers	right-left: 6.8s
		Clean back of hands	right-left: 13.6s
Leaving handwashing area	Skips washing hand	Oh No	right-left: 1.8s
	Proper handwashing	Very Good	up-down: 2.24s
Verbal/physical interactions	Asking name of robot	My name is Pepe	right-left: 3.4s
	Asking about robot's house	This school is my home	right-left: 2.5s
	Multiple questions	Can't hear	right-left: 1.35s
	Long interaction	Don't you want to go to class?	right-left: 6.8s
	Undefined queries	I don't know I'll tell you later	right-left: 2.5s
	Bye	Tata, Bye	up-down: 1.12s
	Touching/harming robot	Please don't touch me	right-left: 1.8s

TABLE I
BEHAVIOUR MAPPING

India (March 2019). A typical school day starts at 10 A.M. with prayer and classes run till 12:30 P.M when the lunch break begins. In between they have a short break at 11:30 A.M. The lunch break lasts until 2:00 P.M and the classes proceed till 3:30 P.M. The school has two toilets, one each for boys and girls. The wash basin with four taps is situated next to the toilets. As noted by Abraham et al. [19], washing hands with soap on key occasions such as after defecation and before handling food can possibly prevent up to 30% of diarrhoeal episodes. These two aspects of the school experience - access to toilets and to food became the key points for the robot intervention.

B. Demographics

The school has 100 students from grades 1 to 4 aged between 5-10 years. 27% of the student population comprise of children from the scheduled castes & tribes (SC/ST), reflecting the demographics of the district where 22.5% of the population are from these communities [20]. The SC/ST segment of the population in India are the most affected by poor sanitation and hygiene conditions owing to minimal economic opportunities and poor levels of literacy and education.

C. Procedure

The robot was controlled remotely by wizard who watched a live camera feed through 2 cameras placed at the water tap, one from above and a front camera on the face of the robot. The wizard triggered the actions on the robot as per the events mentioned in Table I. The Wizard was seated in the building next to the handwashing area hidden from view of the students.

1) Robot Intervention: On day 1 of the Robot Intervention, the children were initially given a briefing about the study. They were told *"We have a visitor in our school, its name is Pepe, is here to tell/deliver you a very important message. You can find Pepe near the water tap, so during your break see what Pepe has to say. Pepe will be here with us only for a few days (we did not tell them how many days). Then Pepe will go away to another school to deliver this message to children like you."*

On the first day we put two A3 sized posters of the seven steps of handwashing onto the wall adjacent to the wash basin. The robot was placed at the designated spot (Fig. 2) soon after the school began. We designed the initial exposure of the robot to be a controlled one so that every child gets atleast one opportunity for the robot to instruct them through the 7 steps of handwashing [21].

At a time 8 children were asked to stand at the handwashing area, 2 children per tap. One of the researchers acted as a facilitator who demonstrated the proper handwashing steps following the robot's lead after it introduced itself and its intention, and then proceeded to guide through the steps. For all the 100 children, this took just half an hour, after which they proceeded to have their lunch. The rest of the interactions between the students and the robot was through the "In the Wild" mode for the following 2 days.

On the last day 3 after robot intervention, the robot was taken to each classroom to encourage the students to take a handwashing pledge. This was followed by an impromptu demonstration of the working of the robot after the teachers requested one for the 3rd and 4th grade students to encourage interest in the STEM disciplines.

The robot encouraged the students who were coming near the robot to wash their hands after using toilet and before having food during robot intervention (Fig. 2). In our study we found that the influence of the social robot over changing handwashing behaviour was significant (40%) and the students also washed their hands with better technique after the robot intervention [22].

D. Interview Design

Conducting surveys and interviews with children have been affected by various issues including unequal power

Fig. 2. Robot Interaction - A: Students showing hands to Pepe, B: Group handwashing session, C: Students talking to Pepe, D: Post lunch interaction with Pepe

structures between the adult interviewer and the child, including suggestibility. We followed De Leeuw's [23] suggestions in designing the surveys for the children.

Consent was obtained from the school authorities including the principal and the teachers who were the guardians of the children. Informed consent was obtained from the children. The students' data including survey responses were anonymised. All data was collected within the confines of the school. Locations for the interviews were intentionally chosen to be outside classroom and official environments. Interviews were planned in the afternoon sessions after they had interacted with the robot.

1) Individual Students: The individual interviews were designed to gauge the students' perception of the robot along multiple domains, including perceptions of identity, likeability, gender, age, animacy and exposure to technology (see Table II). Direct perception questions dealt with questions on the student's understanding of what Pepe is. For this, the research team made sure that the word "robot" was never used by the team during the interviews and the teachers instead referring to the robot by name. This was done to ensure that pre-conceived notions of what a robot is or what a robot can do based on exposure to movies and cartoon shows affect their perception of Pepe. In addition some questions sought to measure the exposure and accessibility to technologies like smart phones, games and electronic toys, which has implications for the design of social robots for this audience.

The students were also asked to rate how much they liked Pepe on a Smileymeter, a visual likert scale developed by Read et al. [24] as part of the "fun toolkit" for user studies in child computer interaction. We also used another measure from the fun toolkit, called the Again-Again test which had the children answering whether they would like to see the robot again, which Read et al. suggests is a much more reliable manner of understanding if the child really likes using some piece of technology (i.e if they like it, they would like to interact with it again).

Category	Type	Question
Perception	Identity	What did you think Pepe is?
	Again-Again	Would you like to see Pepe back in the school after vacation?
	Likeability	How much do you like Pepe?
	Age	Is Pepe younger or older to you?
	Animacy	Is Pepe alive? Why is Pepe alive/inanimate?
	Gender	What was Pepe's gender? Why is Pepe a male/female?
Exposure to Technology	Phone Use	Have you used a smartphone? Have you played games on it? Which games?
	Electronic Toy Use	Have you used battery operated toys? What were they?

TABLE II
INDIVIDUAL SURVEY QUESTIONS

Students were selected randomly by the researchers referring to the attendance register (N = 43), omitting students and recruiting others into the list if there was an imbalance in the gender or caste demographics. There were 22 male participants and 21 female participants selected for the interviews. The interviews were conducted by 3 interviewers at locations outside the classrooms to remove the exam-like expectations students may get if put in a classroom. The interviewers took care to sit next to the participants, again to dispel any notions of a test being conducted.

The participants were informed that if they choose, they could leave the interview and go back to their classrooms or whatever it was they were doing before the interview. Participants who asked about the purpose were informed that it was to understand what they thought of Pepe after meeting it. Care was taken not to give any idea that the interviewers were part of the team that built the robot, as it will only amplify the existing tendency among young children to please adults. Considering the rural audience, we also followed recommendations by Dell et al. [25] to reduce response bias by making sure not to mention that the robot was made by the researchers present there and to reduce the difference in social status by asking the students to call the researchers as their elder brothers and sisters instead of the traditional Indian school honorific "sir/madam".

V. RESULTS

A. Perception

Identity: In response to question regarding the identity of the robot *"What did you think Pepe is?"*, the 3 major responses were Robot (25%), hand (18%) and don't know (23%), the rest of the responses were spread between human (1), computer (1), friend (3), teacher (3), toy (1), something that talks (2).

Again-Again: The question *"Would you like to see Pepe back in the school after vacation?"*, We found similar results in the Again-Again question responses, with 97% of the respondents (42) indicated that they wanted to see the robot after a few months when their school re-opens. It appears the students had started to develop a bond with Pepe.

Likeability: For question *"How much do you like Pepe?"*, we found that among the 43 respondents, 91% (39) of the respondents indicated using the smileymeter [24] that they like the robot "very much" (rating - 5), 3 liked the robot (rating - 4) and 1 was neutral about it (rating - 3). None of the children indicated a dislike for the robot. Considering the age of the student participants, care should be taken while interpreting the results as Kam et al. [26] found while interviewing children in rural India of a similar demographic to the respondents of this study, that the respondents were not able to understand the meaning of the smileymeter.

Gender: We found that the male and female participants perceived the robot's gender in different ways. Overall, 67% of the respondents thought the robot's gender is male while the rest 33% thought it was a female. Among boys, 91% of the respondents thought Pepe was male while 57% of girls found it be of their own gender. We found a strong co-relation between the participants own gender and the robot's perceived gender (p-value = 0.00077). Reasons given for gender perception were related to voice (60%), appearance (13%), while 27% did not know, one respondent each quoted behaviour and the name of the robot as their reason.

Age: When asked about its age *"Is Pepe younger or older to you?"* 60% said it is younger than them, older (33%), same age (7%). Sandygulova et al. [18] suggests perception about gender and age of social robots is influenced by the gender of voice used by the robot and younger children prefer a robot with a matching gender.

Animacy: When asked if Pepe was alive or not, 72% of the students thought it was alive (referring to its ability to talk as the main reason) whereas 23% thought it was not, with 2 students not having a clear answer. When comparing the perception of animacy of the respondents with the responses along the two exposure to technology scales (use of phones, exposure to toys), the p-value is not significant at a 95% confidence interval.

B. Exposure to technology

In the exposure to technology section of the questionnaire, we found 74% of the respondents having exposure to smartphones including using them for playing games, watching videos, searching in Google among other things. However the exposure to electronic toys was lesser compared to that of smartphones with only 63% of the respondents indicating that they have played with such toys. None of them had interacted with a robot before.

VI. DISCUSSION

A. Perception

Though unintentional, we found such social robots to be useful in understanding children's perception of animacy. From the second day of intervention, the children reported they had started to tell stories from their home and friends to the robot. The researchers observed the students asking advice from the robot on matters related to their academics and health, showing that they formed a strong bond based on trust with the robot. On Day 3 of RI, the teachers requested for the students to be shown how the robot works to encourage their interest in the STEM fields. Students commented on the robot - *"it's alive with a yellow light as it's brain, speaker as it's ear, camera as it's eyes, it has phone as it's mouth so it's alive"* and *"Pepe is our friend, if Pepe had a body, hand and legs it would look same as us and it's not a toy"*.

B. Cultural Factors

During the group discussion, the students were asked about the robot's appearance and if they would like to see it any other design. The participants mentioned they would like it to be a cat's face. The reason was they could take it home and pet it. When the interviewers asked if a dog's face would also be appropriate, many of the students responded saying that they would not like that because dogs are considered unclean in their religion. Many of the students also commented that they had cats at home. Students with other religious backgrounds also agreed with this suggestion. This underscores the need for social robot design to take in cultural perceptions of form and symbolism.

In previous hygiene promotion programs research has indicated that contextual factors such as ethnicity, age, gender, and socio-economic status of the health promoter is influential in success of the intervention. De Buck et al. [27] suggested, younger age of the facilitator was thought to be associated with a decreased knowledge translation to family members or older age might be a barrier for the implementation of handwashing interventions. The authors also mention the importance of gender of the health promoter was a factor that could influence program effectiveness, for example women would not ask specific sensitive questions, such as birth control or personal hygiene, to a male health promoter. These factors should be considered while designing social robots especially in rural context in developing countries where the cultural influence is significant in determining the success of the intervention.

C. Limitations

The intervention was short term due to logistical and practical challenges to deploy the system for several days. So we anticipate the responses from the participants could have been influenced by novelty effects. Also as the robot was tele-operated the participants' responses could have been biased towards thinking that the robot is intelligent. Although we did inform the students at the end of the study that the robot was tele-operated.

VII. CONCLUSION AND FUTURE WORK

Taking into account the indicators on social robot design by the children who participated in the study, we believe there is a vast potential for the use of cost-effective social robots and agents in behaviour change interventions. We seek to extend this work by developing autonomous capabilities for the robot by identifying the most effective robot behaviours that has an impact on behaviour change. Such autonomous cost-effective technologies can enable an effective implementation of the recommendations given by Vindigni et al. [9] to reduce the various problems plaguing intervention design in promoting hand washing including but not limited to unreliable self-reporting.

ACKNOWLEDGEMENT

We thank all the school children for participating in our study. We also thank Amrita Vishwa Vidyapeetham university for providing seed funding for the project, and in particular to Mata Amritanandamayi Devi (Chancellor) and Dr Balakrishnan Shanker (Dean) and for all their support and encouragement for this project. We express our gratitude to Ms Usha P.R (School Principal), Mr Abdul Rahman and all the school teachers for assisting this study and sharing their valuable feedback. We also thank Mr Amritesh for designing Pepe's vocalizations, Mr Deepu D Sasi for realizing our electronics design on board & the 2ndFoundation Makerspace team for helping fabricate the robot.

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