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Influencing Hand-washing Behaviour With a Social Robot: HRI Study With School Children in Rural India

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***Abstract*— The work presented in this paper reports the influence of a social robot on hand washing behaviour on school children in rural India with a significant presence of indigenous tribes. We describe the design choices of our social robot to cater the requirements of the intervention. The custom built wall mounted social robot encouraged 100 children to wash their hand at appropriate time (before meal and after toilet) using the correct handwashing technique via a poster on a wall. The results indicate that the intervention using the robot was found to be effective (40% rise) at increasing levels of hand washing with soap and with a better handwashing technique in ecologically valid settings.**

I. INTRODUCTION

Social robots as tools for persuasive technologies can interact with people to change their attitude and/or behaviour [1]. Persuasive technology can motivate, remind people, encourage, and help them reach their goals. The effect of such technology interventions can be more effective especially for subjects who have the least exposure to modern technology and tools. Most social robotic applications are envisaged to fulfil urban needs in developed countries, there is lack of attention from both the HRI research community and industry to explore social robotics applications that can be effective in developing countries. People from rural communities who have limited exposure to different technologies owing to their geographically remote or reduced economic background may perceive robots very differently.

Hand-washing with soap has been included in UN's Sustainable development goals for sanitation and hygiene. Hand-washing with soap is one of the most cost-effective public health interventions in reducing the burden of global infectious diseases [2]. It could save more than a million lives a year from diarrhoea [3] and prevent respiratory infections, the 2 biggest causes of child mortality in developing countries [4]. Children are especially vulnerable to get infected due to improper hand hygiene. Each year, approximately 525,000 children die from diarrheal diseases, making it one of the top killers of children globally [5]. A review of more than 40 studies found that handwashing with soap can prevent approximately 40% of diarrhoea cases [6].

Handwashing promotion programmes are being implemented widely in developing countries to improve child health and development. Since schools are crucial settings for disease transmission, school-based interventions can ease the overall burden of communicable diseases on the community. Previous research suggests that hygiene promotion programmes mostly focus on educating people about health, germs and disease often using tools such as games, videos, posters, leaflets and charts [7]. This can be a very resource intensive task, and such approaches rarely result in positive, sustained behaviour change [8]. Evidence suggests the disruption of the physical and social setting where the hand washing behaviour should take place by placing eye-catching cues and visual reminders can lead to more successful interventions [9]. In essence the intervention needs to be surprising, simple, attractive and engaging to its target users.

There have been several promotional approaches to behaviour change by means of hygiene messaging, psychosocial theory, community-based working, social marketing, incentives or advocacy [10]. In regards to behavioural science it is known that people change their behaviour when they know they are being watched, also known as *"Hawthorne Effect"* [11]. There also is a strong evidence that humans modify their behaviour in presence of other people [12], [13]. A field study by Pfattheicher et al. [14] showed a significant increase of hand hygiene compliance when a picture of watching eyes was presented in a public restroom.

However none of the previous hand hygiene interventions have considered the use of technological interventions using social robots. In health applications, social robots as tools for persuasive technologies can interact with people and be effective to change their attitude and/or behaviour [1] as humans have a tendency to anthropomorphize social robots. The physical presence of a robot impacts human perception and behaviour [15]. In this research we investigated if social robots can influence behaviour change to increase hand hygiene compliance.

II. RELATED WORK

There have been only a few technology based interventions for promoting/encouraging handwashing, Judah et al. [16] installed wireless devices in highway service station restrooms to record entry and soap use. Two text-only messages for each of 7 psychological domains were compared for their effect on soap-use rates. Disgust related messages was the most effective for men, increasing soap use by 9.8%, however for women it was not very effective. The authors concluded that public health interventions should target men and women differently.

Hussam et al. [17] investigated the use of nudges and rational habit theory applied to handwashing behaviour at the

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critical moment just before preparing food or eating. They measured handwashing by a soap dispenser embedded with time-stamped sensor. They observed that the participants who received monitoring and incentives increased handwashing when compared to groups that only received a dispenser; and these effects persisted even after monitoring or incentives were removed.

A study from Biran et al. [9] indicated significant increases in handwashing with soap can be achieved using a scalable intervention based on emotional drivers for example disgust (the desire to avoid and remove contamination) was effective in signicantly increasing the prevalence of handwashing with soap in villages in rural India.

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 coloured paths were painted from toilets to the handwashing station, and footprints and handprints were painted on the path and handwashing station [18].

A study conducted in In Kathmandu, Nepal, by Neal et al. [19] implemented an approach to improve handwashing behavior at 24 schools. Nudges were introduced by using mirrors above handwashing stations and signs with messages to invoke disgust or provide information. Also painted footsteps as a path to handwashing stations. They observed that handwashing rates increased from around 9% to more than 65% also Students also showed a significant preference for using sinks with mirrors, even when those sinks were located farther from a latrine.

In regards to conducting HRI studies with rural populations Deshmukh et al. [20] in a pioneering HRI study as a means to understand perception about the robot and technology acceptance 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.

This research brings together the some aspects from previous hand-washing research and investigates the effects of social robots as persuasive tools to influence behaviour change pertaining to hand hygiene compliance. To the best of our knowledge this combination has never been attempted before especially in a rural context.

III. ROBOT DESIGN

We designed our own low cost (approx 100 USD) robotic platform robot called “Pepe” (Fig. III) with minimal expressive capabilities that can cater to the needs specific to handwashing. According to Bartneck et al. [21] 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

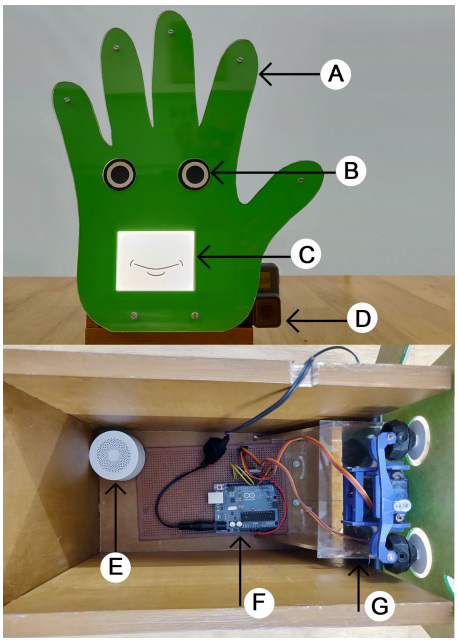

Fig. 1. Robot Design
(Front View) A: Robotic Face (Acrylic), B: Eyes 2 DOF (yaw and pitch), C: Phone displaying robot mouth, D: Front-facing camera, (Top View) E: Speaker, F: Micro controller, G: Eye Mechanism

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.

We wanted to have eyes on the robot, this especially important in this context, as it is known people change their behaviour when they know they’re being watched, also known as *“Hawthorne Effect”* [11]. We 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. [22]. The eyes could produce up-down, left-right movement as described in Table I.

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 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 [23]. The robot’s mouth was a fixed animation a sequence of mouth positions played back at around 10 FPS shown on a mobile screen while the robot was talking.

IV. METHODOLOGY

The aim of this study was to investigate if social robots can influence hand-washing behaviour of school children in a rural village. Our study assumes that soap and water are readily available for the participants to wash their hands.

A. Environment

The study was conducted in a government primary School (March 2019) in a rural village Wayanad district in the southern Indian state of Kerala, India. The school has two toilets, one each for boys and girls. The wash basin with four taps is situated next to the toilets. The students have access to the government's scheme for free, nutritious lunches, which is a motivation for many underprivileged families to send their children to schools. In addition to this initiative, there is also a free breakfast initiative for tribal children. A typical school day starts at 10am with lunch break between 12.30 P.M - 2.00 P.M. and the classes finish at 3:30 P.M.

B. Participants

The school has 100 students from grades 1 to 4 in the kindergarten class aged between 5-10. 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 [24]. 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. Intervention Messages/Behaviour

Washing hands with soap on key occasions such as after defecation and before handling food is regarded as an effective means of preventing the transmission of diarrhoeal pathogens, preventing up to 30% of diarrhoeal episodes [25]. The intervention behaviour provided by the robot were designed to target these key moments i.e. before meal and after the use of toilets. 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.

D. Procedure

1) Exposure to Soap & Camera: We designed a week long pre-intervention step and placed one soap in a soap box for each of the 4 taps so that the novelty of soaps wear off. We also placed an overhead camera so that the *"Hawthorne Effect"* [11] is minimised as the children get used to the camera over the week. We found from the school authorities that the children are quite familiar with security cameras which are used across the district in monitoring plantations.

2) Pre-Robot Intervention Observation [PreRI]: We observed the baseline handwashing behaviour after the children were exposed to a camera and soaps. The observation was conducted by placing a GoPro camera from the top of the washing station. Video data was recorded for one full day.

3) Robot Intervention [RI]: The children were 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."*. The robot was also attached to a wall next to the water taps as this was the main location for handwashing activity was expected to happen.

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

- Day 1 - 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 A) soon after the school began. The Wizard was seated in the building next to the handwashing area hidden from view of the students. 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 [26]. 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. Several interventions for example Galiani et al. [27] focus on improving handwashing skills through the use of demonstration of correct technique, we adopted the same approach. For all the 100 children, this took about 30 minutes, after which they proceeded to have their lunch. The rest of the interactions between the students and the robot was in the wild. The robot encouraged the students who were coming near the tap to wash their hands after using toilet and before having food during RI (Fig. 2).
- Day 2 - The schedule was similar to Day 1, except that there were no controlled sessions for children from grades 2, 3 and 4.
- Day 3 - The robot intervention continued in Day 3. After the RI was finished in the late afternoon session

		Robot Behaviour (WOZ)	
Activity	**Children's Behavior**	**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

following the lunch break, the robot was taken to each classroom to guide the students to taking a hand-washing pledge. This was followed by an impromptu demonstration of the working of the robot after the teachers requested one for 3rd and 4th grade students to encourage interest in the STEM disciplines.

4) Post-Robot Intervention Observation [PostRI]: The students' handwashing behaviour was recorded 6 days after the last day of RI, using the same camera setup as in PreRI.

V. RESULTS

A. Hand Washing Behaviour

For analysing the videos we used BORIS, an event logging software for video/audio coding and live observations [28]. We counted the number of steps completed by the students in reference to the posters on the wall near the handwashing area and the duration for each step. In particular the events after visits to the toilet and before meal. To access the quality of hand washing in our analysis we assume that completing 6-7 handwashing steps is Above Average, 4-5 is Average, 2-3 Below Average, 1 is Basic, no hands washed is Poor. We also calculated the time taken for each handwashing occurrence. Since it was not feasible to identify individuals the analysis was performed objectively.

The Table II summarises all occurrences which were rated for the 3 conditions (Pre-RI, RI and Post-RI) in the study. The handwashing count after toilets can't be relied on completely because of children who go to the kitchen garden passing the toilet where the camera could not see. But the chances of this happening are very rare.

1) Handwashing Effect over conditions: The graph in figure 3 summarises the results for 3 conditions. The bars (Y-axis) on the graph represents the percentage of occurrences in relation to the total number of occurrences for each event on X-axis. Robot intervention (RI) occurrences are averaged for 3 days of the intervention. For No Hand Wash After Toilet, we see a drop in relative occurrences from Pre-RI (39.58%) to RI (24.18%). Also a significant drop from Pre-RI (35.41%) to RI (10.36%) for No Hand Wash Before Meal. And a very significant increase for overall Hands Washed from Pre-RI (25%) to RI (65.44%) nearly a 40% increase. So it appears during robot intervention students washed their hands regularly and it significantly increased levels of hand washing also reducing the overall count for both No Hand Wash Before Meal and No Hand Wash After Toilet comparing pre-RI and post-RI.

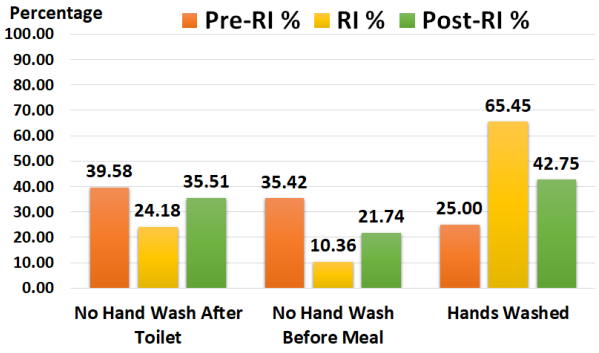

Fig. 3. Overall Handwashing

However we also see a rise in numbers for both No Hand Wash Before Meal and No Hand Wash After Toilet for post-RI in comparison with RI which suggests after the robot was removed the students again went back to the old habit of not washing their hands. Nevertheless we observe that for overall Hands Washed pre-RI (25%) and post-RI (42.75%) shows that more number of students retained the habit 6 days after RI which is a positive indication.

2) Handwashing Quality: To access the quality of hand-washing, we analysed the data based on rating given to each hand washing occurrence (Table II). Graph in figure 4 summarises the overall quality of hand washing for each

Condition →	Pre-RI		Day 1 RI		Day 2 RI		Day 3 RI		Post-RI	
Rating ↓	A-Toilet	B-Meal	A-Toilet	B-Meal	A-Toilet	B-Meal	A-Toilet	B-Meal	A-Toilet	B-Meal
Basic	9	2	17	35	6	17	1	19	2	18
Below Average	1	0	2	1	14	9	1	0	2	2
Average	4	1	3	1	17	10	1	0	1	0
Above Average	2	1	34	29	24	13	44	43	20	10
Poor (No Hand Wash)	38	34	79	15	30	13	17	26	49	30
Total Occurrences	**92**		**216**		**153**		**152**		**134**	

TABLE II

HANDWASHING BEHAVIOUR SUMMARY. EVENTS- B-MEAL: BEFORE- MEAL TIME, A-TOILET: AFTER USAGE OF TOILET

rating for the 3 conditions. The bars (Y-axis) on the graph represents the percentage of occurrences in relation to the total number of occurrences for each rating on X-axis. Robot intervention (RI) occurrences are again averaged for 3 days of the intervention.

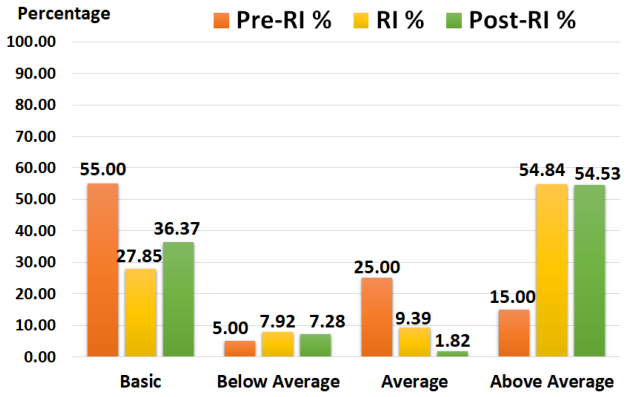

Fig. 4. Handwashing Quality

We observe that more students practised Basic and Average handwashing technique Pre-RI compared to RI and Post-RI. We see a significant rise (40%) in Above Average handwashing technique during RI (54.84%) and post-RI (54.53%) in comparison to pre-RI (15%). Suggesting that the quality of handwashing was increased during and after the robot intervention 6 days after of RI, again showing a positive effect of the robot intervention in retaining good hand hygiene compliance.

B. Handwashing duration

We calculated the mean duration the participants spent on each of the event, hand washing before meal the Above Average mean time was 21 seconds Pre-RI and 98 seconds Post-RI, almost a 5 times increase. The overall mean time of washing hands was 43 (s) Pre-RI and 113 (s) Post-RI again a substantial increase in mean time Pre-RI and Post-RI.

There was also a substantial increase in the mean time of Above Average handwashing for hands washed after toilet from 2.4 seconds pre-RI to 21 seconds post-RI. Average handwashing after toilet increased from 20 (s) pre-RI to 53 (s) post-RI, Below Average 41 (s) pre-RI to 54 (s) post-RI, and 16 (s) pre-RI to 27 (s) post-RI for Basic handwashing technique. This result clearly reflects that the intervention from the robot was influential in increasing the time spent for hand washing. The handwashing duration for RI could not be calculated due to lack of resources and high video coding time demands.

C. Handwashing knowledge

In addition, the student's knowledge about proper handwashing procedures were tested under 3 questions post-RI. 43 students were randomly selected, (22 male and 21 female). They were shown a series of cartoon images of children writing, playing, watching television and eating food (fruits) and asked to point out which activity should be preceded by proper handwashing with soap. For the questions dealing with measuring handwashing knowledge, we found that 98% of the students answered the question on identifying the activity to be followed by handwashing with soap. 95% of the students also answered the question on identifying the correct activity preceding which handwashing with soap has to be done. On asked to mime the motions of the different handwashing steps where we counted the number of correct steps demonstrated of the 7 total steps, we found the mean score M = 5.33 (SD = 1.34), indicating above average knowledge on hand washing techniques with the participants.

VI. LIMITATIONS

We also did not study the effect of social facilitation in our study [29]. We cannot confirm how much the handwashing behaviour was influenced by other students present at the water tap. Our study was a short term intervention hence we could not monitor the effects over a long-term period due to resource limitations and practical challenges. Our research does not show evidence if this behaviour change prevailed weeks after the robot was removed. We also did not study the influence of novelty effect as the children might have to drawn to the robot and follow what instructions the robot was giving due to its novelty. Previous research indicates that handwashing behaviour change takes time, and a one-off intervention may not be sufficient to achieve a sustainable habit formation [17].

We also found that students' knowledge about handwashing was good (section V-C), however we had not measured their knowledge about handwashing before the intervention so cannot conclude that their knowledge was enhanced after the intervention. The robot was tele-operated, the participants' behaviour could have been influenced by perceiving that the robot is intelligent. Although informed the students at the end of the study that the robot was tele-operated.

VII. Conclusion and future work

Overall the influence of the social robot on changing handwashing behaviour was significant in increasing (40%) levels of handwashing and with a better technique during the robot intervention more than pre/post robot intervention indicating *"Hawthorne Effect"* [11]. Most HRI research is carried out in urban environments with subjects from developed countries. To the best of our knowledge this is the first HRI study carried out in rural environment "in the wild" with children from an impoverished background.

We believe the impact of social robots as tools for behaviour change can be more profound with subjects from developing countries. This is an essential step towards informing design decisions for robotic applications that seek to address the underserved populations of the world. In the future we would like to develop autonomous capabilities for the robot and deploy the robot over a long-term and study if the handwashing behaviour change is sustainable. An autonomous system can also provide real-time feedback, collect data and will also reduce the burden of resource intensive handwashing interventions using traditional approaches like unreliable self-reporting [27].

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