HAKSH-E: An Autonomous Social Robot for Promoting Good Hand Hygiene among Children

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***Abstract*— We present *"Haksh-E"*, a social robot for promoting good hand hygiene among children. This robot can supply valuable objective data to stakeholders and the UN to monitor progress on targets for UN SDGs 3 and 6. We discuss the design parameters of *Haksh-E* and a pilot study conducted with 10 children between the ages 6-11 years hailing from rural and urban locations in Southern India. The children provide insights on their perception and acceptance of our robot prototype over various dimensions including likeability, perceived intelligence, anthropomorphism, trustworthiness, age, and gender. Our results suggest that *Haksh-E* has the potential to be used in educational and children-centered spaces to promote handwashing behavior change.**

I. INTRODUCTION

Robotics and Artificial Intelligence are making huge inroads in areas as diverse as consumer applications, agriculture, the manufacturing industry, and the education sector. These advances have brought down the cost of robotic equipment and the resulting democratization opens up new avenues for the application of robotics for humanitarian applications. In the current COVID-19 pandemic and the post-pandemic era as well, one key trend that is emerging is increased awareness of health. Therefore, a potential application of social robotics is to promote healthy habits such as increased hand hygiene, wearing masks, and maintaining social distancing, especially among children. Our domain of interest is the design and development of an autonomous social robot companion that can monitor handwashing practices, provide nudges for good hygiene practices as well as engage children in conversations to facilitate learning of facts and concepts around hand hygiene and reinforce positive habits in children in the long term.

By a social robot, we mean an embodied artificial agent that interacts with humans, communicating in a human perceptible way and a socially accepted manner [1]. We are currently designing the robot as an autonomous agent to be used in an "active" mode wherein the robot will actively interact with children and nudge them to adopt positive handwashing behaviors. The robot is connected to an overhead camera which captures video data of children hand washing and feeds it to a deep learning convolutional neural network (CNN) model running on the robot's processor. The CNN model classifies the steps of handwashing according to the World Health Organization (WHO) guidelines to provide data on the quality of handwashing performed by the child. The authors are also designing a conversational AI agent to help the robot interact with the children. The social robot developed can also be used in a "passive" observer mode to monitor the effectiveness of other hand washing behavior change initiatives. The robot, both in active and passive mode, can supply valuable objective data to stakeholders like the school authorities, health departments, the local government, and the UN to monitor progress on targets for UN SDGs such as SDG 3 and SDG 6 [2].

Existing commercial social robot platforms are cost-prohibitive [3]–[5] especially when they are to be deployed at scale in developing economies. This necessitates a custom-designed robot with low-cost components which is made with manufacturing technologies accessible in developing countries. In 2019, AMMACHI Lab's team carried out a *Wizard of Oz* study in a rural school in India with an ultra-low-cost prototype called *Pepe* to analyze the effectiveness of such a robot to promote hand washing behavior [6], [7]. *Pepe* was a hand-shaped robot with a small video screen mounted behind its green acrylic exterior. It was installed on a wall near school washrooms. The results showed significant ($> 40\%$) improvements in terms of change in handwashing habits of young children in schools pre and post-intervention. Furthermore, *Pepe's* potential to interact with children in vernacular languages showed its potential for deployment in different community interaction scenarios outside of a school setting such as in child care centers, food courts in malls, family recreation parks, and venues for large events to name a few.

In this paper, we present the initial design of *Haksh-E*, the autonomous version of *Pepe*. The name *Haksh-E* was given to the robot as a portmanteau of two words from the Sanskrit language that means "hand cleaning". We chose this name as it was uncommon, yet easy for children to recall. Moreover, it was a gender-neutral name. We conducted a pilot study to get initial feedback from children and evaluate their perception and acceptance of our robot prototype. We will also share the results of this quantitative interaction study.

II. PRIOR WORK

As stated earlier, cost-effectiveness was an important design consideration for us. Nevertheless, prior research suggests that physically present, embodied robots have several advantages over the less expensive, on-screen virtual robots. Hence we designed *Haksh-E* as a physically embodiment agent. Research by Wainer *et al.* [8] indicate that users find a co-located physically embodied agent more enjoyable due

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to their ability to engage, which in turn leads to better social acceptance as compared to a remotely operated agent [9]. In another study, individuals were more responsive to the commands from a physically present robot than those from an on-screen robot [10]. An embodiment also gives the potential to enhance communication with users by using multiple communication channels such as proxemics, oculesics, and gestures [11]. Out of these three non-verbal communication channels, we focused mainly on oculesics, i.e. eye-related non-verbal communication, for our first prototype of *Haksh-E*.

Kidd *et al.* [12] stated that several features are desirable in social robots for long-term interaction, which include: eye-contact, ability to direct gaze at users, speech, head, and arm gestures, etc. The exact set of features depends upon the type of interaction desired. For a social robot, the gaze is important as it can convey mental states [13] and augment verbal communications. According to Admoni *et al.* [14], for a robot designed for teaching, *mutual gaze* expresses engagement and attentiveness. Onuki *et al.* [15] observed through experiments that a round eye shape with a large iris was most suitable for *referential gaze*. Along with a *mutual gaze*, a *referential gaze* might also be useful for the handwashing intervention scenario, wherein the robot can look at the soap dispenser or the tap when giving verbal instructions. Given these research findings, we chose to concentrate on speech (see Sec. IV-B) and oculesics for *Haksh-E* in the first prototype iteration.

The shape and size of the eyes are important design considerations in social robots when we talk about the gaze. In a study comparing different robot eye types, Luria *et al.* [16] noted that robot faces with lifelike eyes are perceived as more personable than faces with abstract eyes or no-eyes. Robot faces without a mouth or pupils were found to be less friendly and less trustworthy, while faces with eyebrows were ranked higher on intelligence [17]. Therefore, we designed the face of *Haksh-E* to have eyebrows and human-like, large eyes, having irises. The entire face of *Haksh-E* is animated to be more expressive and accurate with its gaze. This also gives the added advantage of the simplicity of design and cost-effectiveness over designing physical eyes for the robot.

III. Design Objectives

We have designed *Haksh-E* for long-term handwashing intervention with the following design objectives:

1) Develop an autonomous social agent to promote proper hand hygiene habits among young children in schools using AI models.
2) Co-design the robot embodiment with children viz., include children in every step of the robot product design cycle as informants.
3) Keep costs low (< $700 or INR 50,000) and minimalistic to also be easy to fabricate.
4) Build an extensible platform that has the potential for augmenting interactions capabilities based on children's feedback.

IV. Design Implementation

In this section, we will describe the functional and non-functional aspects of *Haksh-E* for the design objectives described in the previous section.

A. Physical Appearance

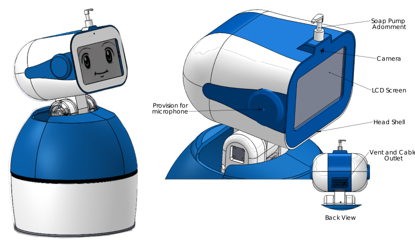

Fig. 1. Robot Model

When designing social robots for a specific application, we have to maintain a fine balance between the degree of "humanness" and the degree of "robotness". A robot with a more anthropomorphic appearance may elicit a higher degree of positive and empathetic response from humans, but only up to a limit, after which the response becomes repulsive [18]. This is called the "uncanny valley". Moreover, a highly human-like appearance can also cause unmet expectations of the robot's capability. Further, a social robot's morphology must match its intended purpose and application [13]. For these reasons, the torso of *Haksh-E* was fashioned as an anthropomorphic soap dispenser and a soap dispenser pump adornment attached to the head (Fig. 1).

B. Robot Speech and Behaviour

One of the researchers (female) recorded all the utterances of *Haksh-E*. We then used *Audacity* to add reverb and change the pitch of the utterances to make it sound gender neutral to avoid bias and be more child-like. This is supported by the findings of Sandygulova *et al.* [19] where the authors stated that the children preferred robots having child-like voices during child-robot interaction. The language spoken by *Haksh-E* is currently English, though we are adding the ability for the robot to speak in vernacular languages. The face of *Haksh-E* was animated using *Adobe Animate* to mimic human behavior (constant blinking, display of emotions such as happiness, sadness, and confusion) by playing a series of frames at 30 FPS. The mouth animation was programmed to lip-sync to the utterances of *Haksh-E*. Additionally, we also added RGB LEDs to the robot's chest, which was used to create a glow based on the robot's emotions.

C. Motion and Degrees of Freedom

We designed *Haksh-E* with a stationary torso and a head with two rotational degrees of freedom (DoF) (Fig. 2). These two DoF permits the robot to maintain its gaze at salient objects and faces in its vision. Limiting the DoF to two also helped in lowering the cost and complexity. The range of motion for pan axis is $-70°$ to $+70°$ and $-15°$ to $+20°$ for the tilt axis. Both axes are actuated by stepper motors driven with silent drivers and synchronous timing belts for quiet operation. We used absolute position magnetic rotary encoders to provide closed-loop position feedback for the motion axes (Fig. 3). Moreover, optical limit switches were also added as an extra fail-safe option. We chose to build the entire motion subsystem using components commonly mass manufactured for hobbyist 3D printers, which further lowered the robot's cost and improved the availability of spare parts.

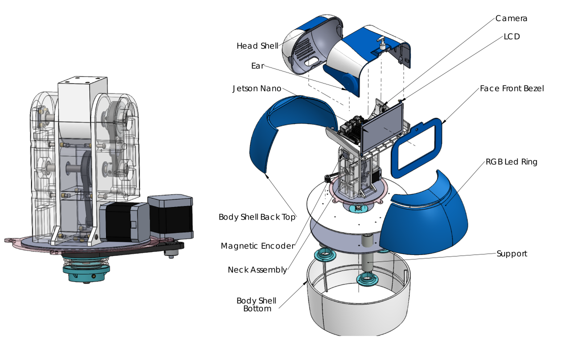

Fig. 2. Pan-Tilt Mechanism (L.); *Haksh-E* Components (R.)

D. System Description

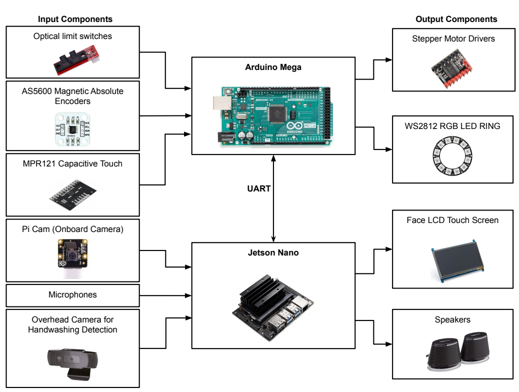

Fig. 3. Block diagram of the components

Computation: The recognition of individual handwashing steps and measurement of other handwashing metrics, face detection, and tracking requires running multiple deep neural networks. NVIDIA® Jetson Nano™ B01 is a powerful Single Board Computer (SBC) that is capable of running multiple neural networks in parallel for image classification, segmentation, object detection, and natural language processing (NLP). All of *Haksh-E's* high-level functions are controlled by a Jetson Nano™. This also allows the future addition of autonomous conversational capabilities. All low-level functions, including reading sensor inputs, actuator, and LED control, are performed by an Arduino Mega, which communicates with Jetson Nano via UART.

Vision System: We designed the vision system to work with two cameras, an overhead camera at the handwashing station, and an on-body camera (Fig. 1), which will function as the robot's "eyes" for recognizing faces and aid in gaze control. The input from the overhead camera will be used to make real-time predictions of the handwashing steps.

Speakers and Microphones: For vocalization, we chose two speakers with a small form factor and a power rating of 5 Watts RMS. They are capable of a sound pressure level of 84 decibels (dB) at a distance of 1 meter, which is much more than the $60-70dB$ range of normal human conversations. The head of the robot has a provision for adding four microphones, which we intend to incorporate in our future prototype design.

E. Fabrication and Assembly

We used rapid virtual prototyping using CAD modelling for the first design iteration of *Haksh-E* which we present here as *Haksh-E* version 0.5 (see Fig. 5). This approach allowed for fast design iterations, validation of motor sizing, interference detection, and manufacturability checks. An exploded view of the fabrication-ready initial prototype can be seen in Fig. 2. We 3D-printed the parts on a BIQU B1 FDM 3D Printer using PLA plastic, and laser-cut flat profiles from cast acrylic sheets using a CW-1610 CO2 laser cutting machine. After assembly, the final cost of the current prototype totaled to $550.

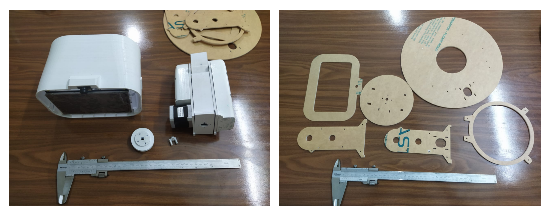

Fig. 4. 3D printed and Laser cut parts of the Robot Head and Neck

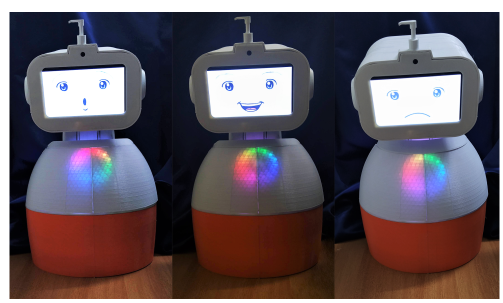

Fig. 5. Various facial expressions displayed by *Haksh-E* version 0.5

V. RESULT

The results of the pilot study we conducted with children are discussed in detail below. The study was conducted with a total of ten children consisting of five boys and five girls between the ages of 6-11 years. All the children are currently studying in schools in two different locations in India - Puthiyakavu, Kerala, and Tirupati, Andra

Pradesh. The parents and children signed the informed consent forms. Due to the ongoing COVID-19 pandemic, we conducted the study online (see Fig. 6). *Haksh-E* was teleoperated by one of the researchers while the children interacted with the robot. The questionnaire used in our study was based on the study by Kalegina *et al.* [17], where the authors included six questions, out of which three questions were selected from the Godspeed questionnaire based on the "Likeability (Unfriendly-Friendly)", "Perceived Intelligence (Unintelligent-Intelligent)" and "Anthropomorphism (Machinelike-Humanlike)" scales and three questions were based on the "Trustworthiness (Untrustworthy-Trustworthy)", "Age (Childlike-Mature)" and "Gender (Male-Female)" of the robot. In addition, we added the question - "Do you like the name *Haksh-E*? If not, why? and what would you like to name the robot?". As shown in Fig. 7, we used a box plot to analyze the responses of the children, which are discussed below.

Fig. 6. The study being conducted in online mode with the children

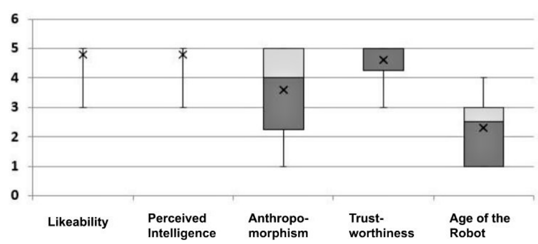

Fig. 7. Box plot showing the responses of the children on the likeability, perceived intelligence, anthropomorphism, trustworthiness and age of Haksh-E

Likeability: Nine of the ten children said *Haksh-E* was very friendly, kind, and good to converse with. One child said that he was not sure because the robot did not converse with him in his native language.

Perceived Intelligence: Nine of the ten children again perceived *Haksh-E* to be extremely intelligent, mentioning that they felt this way because the robot was capable of understanding what the children said and responded accordingly. One child said that he was not sure stating the same reason as above that the robot could not converse with him in his native language.

Anthropomorphism: Six children said that *Haksh-E* was human-like because it "talks like a human" and "has human-like facial features". Three children said that *Haksh-E* was machine-like because ultimately "it is a robot", with one child mentioning that he was not sure because "it talks like a human but is a machine".

Trustworthiness: Nine children mentioned that they would trust *Haksh-E* because "it is friendly and intelligent" and "he told me good words", with one child saying he was not sure.

Age of the robot: Two children said *Haksh-E* was mature and adult-like because "it tells elderly things like handwashing". Five children said that *Haksh-E* was very small and cute. Three children said they were not sure.

Gender: Four children said that *Haksh-E* was male, the reasons being: "looks like a male because of its body", "voice sounds like a male", "robot is a male because I like to play with boys", with 1 child saying "it has good qualities like boys". Four children said that *Haksh-E* was female and the reasons stated by them were: "voice sounds like a female", "her name sounds like a girl" and "her face looks like a girl". It was interesting to note that all the boys perceived the robot's gender as male and all the girls perceived the robot's gender as female. These findings are similar to what was reported by Unnikrishnan *et al.* [6] in their study with the *Pepe* robot. Two children weren't sure if *Haksh-E* was male or female stating that though the robot's voice sounded like a female, its body looked like that of a male.

Name of the robot: All the children except one child liked the name "*Haksh-E*" which we had given for the robot, adding that they did not want to change it. One child responded that he did not like the name and that he would want to give the robot a more meaningful name, preferably his peer's name.

VI. Conclusion and Future work

In this paper, we have presented the design of an autonomous social robot that promotes good hand hygiene practices among children. *Haksh-E* is designed to have two degrees of freedom and has the physical embodiment of an anthropomorphic soap dispenser. Its face comprises of an animated mouth, human-like eyes with large irises, and eyebrows that augment verbal communication using non-verbal expressions. We have given *Haksh-E* a gender-neutral child-like voice based on prior research in child-robot interaction scenarios. The actual cost of fabrication of the robot came to a total of $550.

Results from the online pilot study suggest that children perceived *Haksh-E* to be friendly, intelligent, human-like, and trustworthy. There was some ambiguity observed in the age and gender of the robot, with many children mentioning that they were not sure as to whether *Haksh-E* was a male or female or if it was a child-like or mature robot. Further research needs to be conducted to confirm the effectiveness of the robot to bring about sustained behavior changes on hand washing. Also, studies need to be conducted to test mediation and moderation effects of gender and age of the robot, if any, on behavior change.

As part of our future work, we will incorporate a conversational AI agent into *Haksh-E* to help the robot interact with children and also incorporate an AI-driven hand gesture recognition system to determine the handwashing quality.

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