A Robotic Interface for Motivating and Educating Proper Hand Sanitization using Speech and Gaze Interaction

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Abstract— Hand disinfection in public spaces is of great importance in preventing infectious diseases. However not everyone sanitizes their hands using hand sanitizer dispensers, and even if they do, many of them don’t rub hands for a long enough time for the sanitizing agent to become most effective. For these reasons we designed a robotic interface for automatic hand sanitizer dispensers to motivate people to disinfect their hands more often and for a longer time. We use interactive elements like speech and gaze communication to achieve this. In our in-the-wild studies we have found that using our system resulted in 21% more hand sanitizations and a much longer hand rubbing time, which in turn leads to better public hygiene and better prevention of infectious diseases.

1. INTRODUCTION

Humanity is facing one of its greatest threats in the form of a highly contagious and lethal viral infectious disease, Covid-19. It is caused by the SARS-CoV-2 coronavirus. The disease has resulted in hundreds of millions of infections and millions of fatalities with no definite end in sight. However, even before the Covid-19 pandemic and also after it, there were and will be many other infectious diseases caused by viruses or other pathogens.

There are different ways of combatting these infectious agents: prevention, testing, anti-pathogen treatments and vaccines. Out of these, prevention is always available, while the others might take days, months, or years to develop and administer efficiently. The development of the first fully tested Covid vaccine took about a year, which was the shortest development time for any vaccine. But even before a test, a vaccine, or a treatment, we can start with prevention at day zero to reduce the spread of any future Covid-like pandemics.

Respiratory pathogens need a carrier to travel from one host body to another, which are respiratory secretions. These take the form of a runny nose, cough, sneeze, etc. They can travel through droplets, aerosols or fomites. Droplet and aerosol spread can be significantly reduced by wearing face masks or face shields. Fomite spread instead happens when an object becomes infected with respiratory secretions. These might be picked up by hands which can lead to infections if it is brought to the mouth or eyes of the to-be infected person. In these situations, hand disinfection is of crucial importance, because it removes the pathogens from the person’s hands. Hand disinfection usually takes place either by hand washing with water and soap or hand rubbing of alcohol-based substances. The US Centers of Disease Control and Prevention (CDC) recommends hand sanitization using alcohol-based agents unless hands are visibly soiled, in which case hand washing using water and soap is recommended [1].

Regarding the methodology of disinfectant dispersion, there are two basic methods: manual and automatic hand sanitizing dispensers. The manual devices require a mechanical force on a lever which will release a certain amount of fluid from the refill package. The automatic dispensers have a distance sensor, which detects the presence of a hand under the device, see Figure 1. The sensor signal then activates a motor that exerts a force on the fluid container and the fluid falls on the user’s hand. The automatic devices have the clear advantage of avoiding hand contact with another surface, which can potentially lead to infection.

Hand disinfection refills come in three basic forms: fluid, gel and foam. Gel and foam sanitizers are convenient to use but can be less effective compared to the same amount of fluid sanitizer, according to the Danish health authorities [2], therefore we used fluid hand sanitizers in this study.

In our work we started off with standard automatic hand sanitizer dispenser (AHSD) units seen in Figure 1. These were our baseline units for comparisons. We then improved the AHSDs by building a robot-like interaction interface around

Figure 1. Automatic hand sanitizer dispenser
them', see Figure 2. The interface consists of a 3D printed physical shell containing many hardware elements for supporting interaction: a touchscreen, speakers, an array microphone, a camera, distance sensors and a passive IR sensor, see Figure 3. Using the built-in camera, the robot observes its environment. When a face is detected, the simulated eyes establish eye contact with the person nearby. If they come close enough the robot will start speaking to them to offer hand sanitization. Finally, it will listen to potential responses and continue the dialog or move on to looking for the next person to talk to if the interlocutor is not interested anymore. Once the system was implemented we then tested the AHSDs with the additional interface and compared the results to the regular AHSD units’ performance.

In the following section we will in sequence present related work, describe our technical approach and testing methodology, present and discuss results and finally draw conclusions and set goals for future work.

II. BACKGROUND

A. Importance for public health

Patients admitted to hospitals or elderly fragile people at elderly care centers often have poor immune system and therefore they are more receptive to disease [3]. Because of these conditions proper hand sanitizing for visitors, patients and staff at the public health institutions are very important to break chains of infection and to prevent spread of disease. Furthermore, it is important to sanitize hands often e.g. at the entrance to the hospital, at the elevator, at the entrance to the ward, at the entrance to the cafeteria etc. Even outside the health care environment, hand disinfection is of crucial importance in curbing the spread of Covid.

B. Robots in care

A rising number of robots are used in the health care domain [4]. Some of them participate in clinical tasks as surgery, while others help in non-clinical duties as logistics. Robots do not yet perform surgery by themselves, rather they are tools in robot-assisted procedures. Some are directly teleoperated by people while others have higher level of autonomy, but none of the solutions on the market are fully autonomous [5]. They are employed in different areas of medicine [6]. They are especially useful in minimally invasive laparoscopic procedures [7]. Assistive surgical robots have been found to increase performance of less experienced practitioners [8]. Robotic prostheses are a very useful and prominent application of robotics in health care. They replace missing parts of human limbs. Prostheses can be passive or active [9], where the latter ones can be controlled by signals from the human body [10]. Exoskeletons can be used by patients to remedy lost functionality of limbs [11] or by hospital personnel for helping patients. When patients need to be lifted robotic nurse assistants could be used, which are only starting to emerge [12]. Telepresence robots are becoming more pervasive in the time of the Covid-19 pandemic, as they help in reducing the possibilities to transmit the virus between doctors and patients [13].

An emerging field of robotics in health and elderly care are companion robots which have seen significant applications. The Paro baby seal robot has received positive feedback in elderly care settings, especially for dementia patients [14]. Another popular platform is Pleo, which resembles a baby dinosaur. However, the use of such close-to-human robots might raise some ethical issues as well [15]. Social robots can also be employed as companions in patient and elderly care. These robots usually have more developed interaction skills, e.g. they can have simple speech interactions or react to other communication cues [16].

C. Gaze in human-robot interaction

Gaze is a very important non-verbal human communication channel. People are hard-wired to detect faces and eyes gazing at them, as this has clear evolutionary advantage when defending from predators [17]. In our everyday life we exchange gazes with everyone we meet during the day. Gaze can serve many communicative purposes, even though it is a mostly involuntary phenomenon: we use our eyes to gather information of our environments by looking at it. However, while doing so we also give away information about ourselves, as others can see what we are focusing our visual attention at. Mutual gaze is a strong interaction signal when two agents are looking at each other

1 See how the robotic interface works in this video: https://www.youtube.com/watch?v=r1lPYQyfDx
[18], while joint attention appears when two agents are looking at the same object/person and become mutually aware of this [19]. Robots can use gaze in two ways: they can display their own eye gaze and they can read the gaze of people surrounding them. Gaze is read by eye tracking algorithms and devices. These can estimate a person’s gaze either using geometric calculations or based on appearance and machine learning. Eye gaze is often approximated by its first proxy, head pose, but it has been found that the first provides important additional information for human-robot interaction [20]. Some eye trackers need specific hardware for estimating eye angles, while recently, software-based solutions have become useful for HRI as well [21]. These use only RGB images from simple webcams to determine gaze.

Regarding the robot exerting its own gaze, it serves the purpose of informing others of the robot’s intentions: a simulated set of eyes on the screen does not help the robot to see, but it does inform others who it is focusing its attention at. It has been observed that people who the robot looks at will answer the robot’s speech queries first most of the time [22]. This selection by gaze is an important effect that we will employ in our current research to establish stronger connection with people who the robot is offering hand sanitization to. Articulated, mechanical eyes are the standard for social robots, but despite the Mona Lisa effect, simulated eyes on regular screens can be effective as well [23].

D. Nudging using social robots

Nudging is a concept in which indirect messages are used to influence people’s behavior [24], e.g. make them eat healthier. Even though there are ethical questions regarding nudging [25], here we will focus only on its positive aspects, like improving the health of people. Even though there are many studies on the positive effect of nudging some are questioning its usefulness [26].

Social robots can also be easily used for nudging but only with paying close attention to the above-mentioned ethical aspect [27]. Borenstein and Arkin survey the field of increasing empathy between people using nudging robots [28]. Shachar and Greenbaum give an overview of nudging in elderly care where demented patients can forget to drink water or call their relatives [29].

E. Nudging for sanitization

Nudging in health care can also take place without the need for robots. Iversen et al. studied a hand sanitization improvement system where the dispenser would show a smiley face whenever it was used [30]. At the same time the device was automatically monitoring staff’s hand hygiene compliance using electronic tags. Whenever compliance falls, nudging was strengthened. The long-term study found that their multimodal approach improved compliance, but it is not known if the nudging or the fact that people were monitored improved hand hygiene compliance (HHC).

Mobekk et al. observed nudging of sanitization at a gym over a longer period. They have found that simply adding an image of a pair of observing eyes near the sanitization spray dispenser increased compliance significantly. However, they noticed that in a follow up study this compliance dropped, which warrants additional studies [31]. In the case of our own study, we are working on convincing people to sanitize their hands if they haven’t already done so. We hope to accomplish this using our robotic interface by not so subtle nudging tools as speech and a more subtle nudge: a pair of observing eyes, similar to Mobekk et al. Dissimilar to Iversen et al. we don’t use monitoring technology and feedback for ensuring compliance. We hope to achieve higher HHC using speech and gaze.

III. APPROACH

A. System development

We set out with two types of automatic hand sanitizer dispenser devices readily available on the Danish market produced in two different countries, see one in Figure 1. We made our interface adaptable to both dispensers, with simple adjustments needed to accommodate further standard devices. We applied small electrical changes to the original units to get electrical information on when the dispenser is being activated. This allowed the interaction interface to proceed once the device has already been used. Other than this, we did not make any other changes and the dispensers were able to be used just like any other AHSD without impediments.

The processing unit behind the electronic components was the widely used single-board computer Raspberry Pi 4 and its peripheral components. These provided just enough processing power to adequately complete the task. The outer shell of the interface was designed with interaction and ease of use in mind.

1) Interaction elements

The interactive hardware elements of our interface are depicted in Figure 3 a). We will go through each of these to explain their function and rationale.

a) Camera

The camera was a Raspberry Pi Cam 2.1 with 1080p resolution (1920x1080 pixels). It provides a video stream at 30 frames per second. The primary reason for using a camera was to detect people in front of the robot, to allow appropriate timing for starting conversations. Faces were detected on an additional piece of hardware (Google Coral) which ran TensorFlow Lite facial detection algorithms (MobileNet SSD v2). The 3D location of the person was estimated by knowing the pitch and yaw angles of the face in the camera’s field of view and by estimating the distance of the person based on the size of the head in the image. We only used face detection and never face recognition packages, as it was never our intention to identify or remember people.

b) Eyes

Detecting the location of people in front of the camera was also useful for directing the simulated eyes on the robot’s touchscreen towards the person in front of it. Geometric calculations were made to find where the pupils needed to be placed within the simulated sclera of the eyes to effectively simulate eye contact. This effect was used to easily attract people’s attention: it was hard for people to ignore the robot, as it was staring at them while they were walking by. The eyes were able to convey the effect of mutual gaze despite the Mona Lisa effect [23].
Simulated eye motions and actions were implemented to emulate human eye behavior. The robot was able to blink and was doing so at random time intervals with a mean of about 4 seconds and a standard deviation of 2 seconds. This was done as blinking is an important natural human behavior without which an agent might look very unnatural. An additional eye behavior was exerted when more than one person was present in the robot’s field of view. In this situation it switched its gaze between the detected people with a random period as this is also something inherent to people.

c) **Touchscreen and proximity sensors**

The screen built into the front of the system was touch-enabled. However, the touch capability was never used as this would be hygienically incorrect, especially in pandemic times. Instead, to supplement speech, proximity sensors were implemented on the two sides of the device to enable hand gesture interaction. Nevertheless, hand gestures using the proximity sensors proved to be not too useful in real-life interactions, because they required training and people were mostly in a hurry.

d) **Screen contents**

The screen was divided into three parts (Figure 3 a):

- the top – displaying the eyes,
- the middle – for showing a face mask
- the bottom – for subtitles

The eyes were already described in detail. The mask was added on a suggestion by hospital personnel at our testing location. It was displayed to remind people to wear their face masks. Even though this makes a lot of sense, we could not test its efficiency as virtually everyone was wearing masks, without the need for reminding. The bottom part displayed text which the robot uttered anytime it was speaking. The screen could also be used to display informational messages customized by operators of the device. These messages could include new governmental Covid announcements or hospital news, see Figure 2.

e) **Speech**

In addition to eye contact, one of the most important interaction elements used on this robotic interface were the pre-recorded sentences it was pronouncing. They had the power to attract people’s attention even when they were almost already passing by. Different speech interaction scenarios were tested, see Figure 4. In a longer one it would first offer hand sanitization, wait for an answer and then offer to show a video on how to sanitize hands properly. If people responded affirmatively, as confirmed by speech recognition, a video would start to play showing how to properly apply the hand sanitization fluid. This was part of the educational aspect of the robot. However, a much shorter interaction was found to be more effective, as it was observed that most people do not want to spend a lot of time talking to a hand sanitization device, rather they would want to disinfect their hands and be on their way. In this interaction model, no reaction is expected from people, even though they could respond, and the robot could recognize it. As the second utterance, instead of offering to show a video, the robot gave the advice to rub hands for 30 seconds. This was an important suggestion from our industry partner, as they observed that people tend to sanitize their hands for too short of a time. According to the WHO hand sanitization should be done between 20 and 30 seconds to achieve maximum efficiency in eliminating pathogens like viruses and bacteria [32].

2) **Ease of Use**

The front part of the interface was hinged in a way to allow easy access to the AHSD by flipping it up, see Figure 3 b). This feature was included to be able to change the sanitizer refill easily by service personnel. The bottom of the outer shell was open which allowed the original AHSD device to be used in its regular operation mode, by placing a hand underneath it.
B. Experimental setup

The goal of experimentation was threefold:

1. To check if more people will sanitize their hands when using our system (higher compliance) and
2. To check if people sanitize their hands longer when our system tells them to do so.
3. To gather subjective feedback from users.

1) Hand sanitization ratio – hand hygiene compliance

We aimed at testing if more people would use our robotic hand sanitizer (RHSD) compared to the regular, automatic hand sanitizer dispenser (AHSD). The testing location was at the entrance of the cafeteria at Sønderjylland Hospital’s central building in Aabenraa, Denmark. At first, we observed the usage of the AHSD which was already located there. Two of the authors were sitting at a remote location and were counting the number of uses and passes by the system. We calculated a ratio between how many people used the system and how many people could have used it (HHC). On the second day of testing, the AHSD was replaced by our RHSD and the same procedure was repeated. We calculated the number of uses of the interface divided by the total number of people passing by. In total, we had 363 encounters during the two days, out of which 211 with the regular interface and 152 with the RHSD.

2) Hand sanitization duration

Testing of the length of hand rubbing after hand sanitizer usage was completed at the entrance to our technical faculty’s main building at the University of Southern Denmark, see Figure 6. This location was chosen because of the possibility to observe people who just used the sanitizer without being noticed and because of the vicinity to the experimenter’s office. At the hospital it was impossible to observe people’s hand rubbing time inconspicuously. The length of usage was counted using a stopwatch on a smartphone and noted down with whole seconds precision. On the first day of testing the RHSD was used, followed by the AHSD a couple of weeks later. Special attention was paid to use the same underlying automatic hand sanitizer in both cases with the same type of refill (fluid) as the amount and type of sanitizer agent could influence the length of hand rubbing. In both experiments the short interaction method was applied (see Figure 4 b) with the reminder to rub hands for 30 seconds. A total of 33 observations were made in this case, with 16 people using the regular and 17 using the robotic interface.

3) Interviews

We conducted exit interviews with some of our participants, but only when they finished their interaction with our system. This way all the gathered data is recorded without contamination by the experimenters.

IV. RESULTS

We report here on the percent usage (hand hygiene compliance) and average hand rubbing time difference between the regular and robotic interfaces as well as on subjective feedback from users.

The ratio between those who sanitized their hands compared to the total passers-by for both interfaces can be seen in Figure 7. Applying a chi-squared test it was found that the percentage of use of the robotic HSD was significantly higher than the percentage usage of the regular hand sanitizer device (AHSD) with $\chi^2(1, N=363) = 15.9$, $p<0.001$. The difference between the two was 21%.

Regarding the duration of hand sanitization, the outcome can be seen in Figure 8. The results for the two approaches were compared using a Student’s t-test and the difference was found to be significant with $t(31)=4.02$, $p<0.0001$. It can be seen in the graph, that the hand rubbing time more than doubled on average from the regular interface (circa 7s) to the use of the robotic interface (circa 16s).

Regarding subjective opinions, hospital staff mostly thought the robotic interface was a good idea but did not see themselves as a target audience, as they were already aware of the importance of compliance. Some of the older visitors of the hospital did not like our solution too much, while at the university the great majority of interviewees were very happy with the device.

V. DISCUSSION

In this paper we found two important improvements in hand sanitization efficacy when applying our interactive robotic interface. The first was the increase of compliance with hand sanitization requirements, i.e. the improvement of the ratio of people who sanitize their hands compared to all potential users of the system when using the more interactive solution (see Figure 2) as compared to a regular automatic hand sanitization device (see Figure 1). The improvement is quite significant, at 21% in our experiment. This means that
one in five people are convinced by our interface to sanitize their hands, who otherwise would not have done so.

The other very important observation was that when people are reminded by the interactive interface using speech and gaze to sanitize their hands for a longer time, they really do so. The hand rubbing time increases by 121% compared to the regular interface.

Both of these findings are amounting to a better hand hygiene compliance thanks to the application of human-robot interaction technologies, like speech and eye gaze.

Even though the system could perform speech recognition, only a handful of subjects stopped for a longer dialog with the device. A large majority of them just used the dispenser and went on their way.

It was a regularly observed event during testing that people were almost passing by the RHSD when they heard the reminding voice of the robot asking them if they wanted to sanitize their hands. Many of them even walked back to the interface to sanitize their hands, thus proving our point on the efficacy of speech for HRI.

Other people however had reservations towards the use of the system, as subsequent follow-up interviews revealed. Some of them did not want to be bothered or reminded. Some elderly people even had trouble finding the dispenser’s nozzle or were generally confused by the interface’s design, especially confusing the array microphone (see Figure 3 a) with a push button. However, most people did not have such problems as they used the system without delay. The majority of people also appreciated the reminding voice or thought that it will be useful at least for some who otherwise would not sanitize their hands.

VI. CONCLUSION AND FUTURE WORK

As infectious diseases spread, various pathogens pose a very serious threat to humanity, thus it makes sense to look for solutions which will increase compliance with hand sanitization expectations. We think that the implementation of an interactive robotic interface for hand sanitizer dispensers will lead to better disinfection and thus better infection prevention. Our system which incorporates speech interaction and eye gaze communication significantly increases compliance of users at a hospital. Furthermore, at our university we found that people will rub their hands significantly longer when a hand sanitizing robot suggests them to do so. These powerful nudging and convincing interactive elements have been thus tested and validated in two in-the-wild robot testing scenarios where none of our subjects knew they were participating in an experiment before the interaction, which makes our findings even stronger.

As part of future work, long-term testing of the interface is needed at single locations which will give us definite answers on the presence of the novelty effect. However, we doubt its significant influence as we have conducted multiple day studies both at the university and hospital. Furthermore, we want to test different eye gazing and speech scenarios to figure out which of these interaction modalities causes the large increase in compliance. We suspect that both gaze and speech are influential. Finally, we will introduce improvements to the shell’s design to avoid confusion for the elderly.

REFERENCES


