The Effect of Emotional Expression on the Use of a Hand-Sanitizing Robot

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ABSTRACT

People tend to favor robots that express positive emotions over ones expressing negative emotions. On the other hand, people have been found to use hand sanitizers more when the user's feelings of disgust and guilt are exploited. The goal of this paper is to explore what happens when these two scenarios merge in a hand-sanitizing robot; that is, will people use a hand-sanitizer robot more when it employs positive emotions or when it creates a sense of guilt? The hand-sanitizer robot RIMEPHAS was programmed to express six different emotions (*Joyful, Angry, Sad, Sick, Surprised, and Neutral*) on its display, each accompanied by a voice line, to the user. The recognizability of the modes was tested in a within-subject experiment before testing the influence of the expressions on the usage of the robot in a field trial. The results show a significant difference in the amount of usage, favoring negative emotions.

CCS CONCEPTS

Human-Centered Computing Interaction Design Emperical Studies In Interaction Design

KEYWORDS

HRI, emotions, hand sanitizer robot, field studies

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1 INTRODUCTION

Humans are more likely to interact with robots that convey positive emotions that are perceived as friendly and inviting. These emotions are typically conveyed through anthropomorphic design, for example by giving robots friendly, human-like faces, or by expressing their utility vocally [8][5].

In contrast, the use of non-robotic hand sanitizers has been found to increase when the possible user's feelings of disgust have been evoked. This could, for example, be done by placing stickers of bacteria on door handles, water tabs or buttons, or by using written statements such as "Up to $X\%$ of people don't wash their hands correctly" on mirrors [13][14].

The current study investigates which effect is strongest when the two scenarios are combined with the use of a hand-sanitizing robot. The RIMEPHAS hand-sanitizer robot is equipped with a screen and a speaker, allowing the robot to both look at and talk to users in a timely fashion [12]. Our study seeks to determine whether there will be a significant difference in usage if the robot is leveraging the passerbys' feeling of disgust, as opposed to adopting a friendlier appearance, and hence whether a friendly robot or a feeling of disgust or guilt is more effective in encouraging hand-sanitizer usage.

2 PROBLEM DESCRIPTION

Increasing hand sanitizer usage is an effective way of reducing the transmission of pathogenic diseases [11]. However, the challenge lies in determining the most effective method to incentivize individuals to consistently engage in this preventive behavior.

2.1 Hypothesis

We hypothesize a significant effect when the RIMEPHAS robot expresses either positive or negative emotions on the number of interactions with the robot.

3 BACKGROUND

Much research shows that people like robots that display positive emotions. For instance, Hsieh et al. investigated the influence of non-verbal robot emotional expression by measuring their heart rate variability as an indicator of stress during human-robot interactions with a humanoid robot [8]. Positive emotions conveyed by the robot helped reduce participants' stress levels, while negative expressions induced stress. Furthermore, the participants found the humanoid more enjoyable the more exaggerated the expressions were. Similarly, Chuah and Yu explored how subjects perceived the humanoid robot Sophia depending on the conveyed emotion[5]. Sophia is an anthropomorphic robot, able to express more than 60 different emotions thanks to its 25 artificial muscles, including 12 facial actuators. The study showed that viewers are most likely to have positive feelings about Sophia when showing the facial expressions of happiness and surprise, while the activation of the actuators for sadness results in the opposite.
On the other hand, studies that show that feelings of guilt and disgust induce hand-sanitizing behavior. For instance, Pellegrino et al. tested the effectiveness of sensory reminders of disgust [13]. They found that disgust-inducing sensory cues like disgusting images and sounds were more successful at increasing hand hygiene compliance than visual cues, such as hand washing campaign posters. Sopicha et al. developed an intelligent nudging system for hand hygiene awareness, visualizing the user's hand hygiene as a virtual bonsai tree, using guilt to promote action [14]. The system used face recognition to detect participants passing by, with the the virtual bonsai tree either growing or withering, depending on whether the passerby used the hand sanitizer or not. Sopicha et al. compared four conditions; 1) no nudging, 2) traditional nudging (arrows pointing towards the sanitization station), 3) a communal bonsai tree, and 4) a personal bonsai tree. The study found that the digital nudging system improved the behavior of people in a private organization.
Other research in hand-sanitizer robots has focused mostly on effects of anthropomorphic appearance [1], of motion or speed [2][4] or of speech characteristics [4][7]. The role of emotional expression of a hand-sanitizer robot is thus still open.

4 METHOD

The study utilizes the RIMEPHAS robot, a Robotic Interface for Motivating and Educating Proper Hand Sanitization [12]. RIMEPHAS is an automatic hand sanitizer with a robotic interface using speech and gaze interaction to encourage people to disinfect more frequently and correctly. In spite of its sensing capabilities, in order to ensure comparable response times for all participants, the robot was operated remotely in a Wizard-of-Oz scenario [3]. [1]

[1]Ethical review is not provided at the host institution for non-funded research.

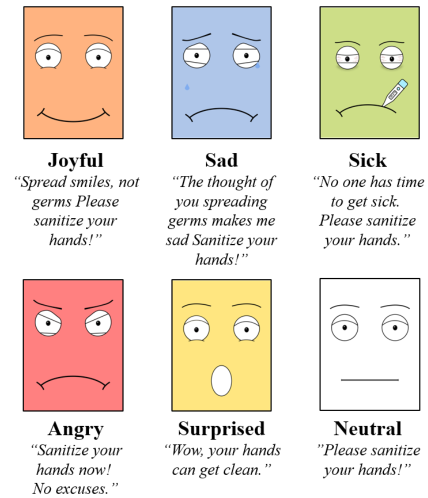

Figure 1: The six faces and voice lines conveyed by RIMEPHAS during both experiments.

4.1 Selecting the modes of emotion

Several emotions, such as anger, fear, or happiness can be conveyed through the use of RIMEPHAS's Graphical User Interface, while only a select few will be shown during the experiments. As such impactful expressions must be selected, to increase the probability of users interacting with the robot, promoting hand-sanitizing behavior. The criteria for selection were 1) recognizability of the emotion through visual and auditory cues; 2) the emotion must be simple and fast to convey; 3) the emotion must be easy to interpret by a majority of the users. Based on the criteria presented above, universal emotions, as presented in Ekman's theory of basic emotions, have come to serve as the basis for the modes of emotion within the study [6]. Universal emotions are readily recognized and understood and are simple to convey. As the only exception to basic emotions, the "sick" expression does not directly convey the emotion of "disgust", but serves as a depiction meant to elicit a feeling of disgust in the user. The faces shown in Figure 1 are categorized as either positive (*joyful* and *surprised*) or negative (*sad*, *sick* or *angry*), with *neutral* as the baseline.

4.2 Sound selection

All robot utterances were synthesized using the free text-to-speech system Genny, voice 'Eric' with a speed of 1.1[9]. The sentences were created based on their capacity to effectively convey the intended emotion, ensuring that the listener experiences a congruent emotional response.

4.3 Experiment I: Mode Recognition & Usage likeliness

To validate the recognition of the modes, a preliminary experiment was conducted, presenting the six different modes to 30 participants. The 30 participants were students, of whom 9 identified as female and 21 as male, at the University of Southern Denmark, between the ages of 20 and 27. All subjects were briefly introduced to the

Table 1: Confusion Matrix showing the results of Experiment I.

	Joyful	Sad	Sick	Angry	Surprised	Neutral
Joyful	**73.33**	0	3.33	0	3.33	0
Sad	0	**100**	10	0	0	0
Sick	0	0	**73.33**	0	0	0
Angry	0	0	10	**90**	0	3.33
Surprised	3.33	0	0	3.33	**86.67**	0
Neutral	20	0	3.33	3.33	6.67	**90**
Don't know	3.33	0	0	3.33	3.33	6.67

project, after which they were shown the six modes, one by one, in randomized order. The participants were asked to complete a questionnaire in which we asked for their age, occupation, and previous experience with robots. Furthermore, we asked subjects to rate their liking of each individual mode on a 7-point Likert scale, asking for each mode: *"What emotion do you believe the X'th mode shows?"* "How much do you agree with the following statement: "I would use this hand sanitizer"?".

4.4 Experiment II: RIMEPHAS user tests

After confirming that participants were able to recognize the expression of the modes, the experiment moved on to presenting the modes on the RIMEPHAS platform in a field trial. The RIMEPHAS platform was placed by the entrance of a canteen at the University of Southern Denmark (SDU) and was controlled in a Wizard-of-Oz approach[3], monitored by the researchers who were located out of sight. The placement was deemed paramount to grab the passersby's attention at the right time, before contemplating their food choice and interacting with counter staff. Each mode was individually introduced to 100 passersby, with the researchers tallying the number of passersby, and whether participants interacted with the platform.

5 RESULTS

5.1 Experiment I: Mode Recognition & Usage Likeliness

Table 1 shows the results of the 30 participants identifying which mode the robot is in, depending on the facial expression and persuasive utterance they were exposed to.

Participants were in most cases able to identify the modes, with the *"sad"*, *"angry"*, and *"neutral"* modes being identified correctly 100%, 90%, and 90% of the time, respectively. It was slightly harder for participants to identify what the expressions *"joyful"* and *"sick"* represented. Many participants initially misidentified the *joyful* mode as either *neutral* or *surprised*, suggesting that it may not have appeared distinctly joyful. This is to some degree true for the *sick* mode as well, where people had better results at identifying the mode correctly after being exposed to the *sad* and *angry* expressions before. The results of participants' ratings of the likelihood of usage of the six expressions are seen in Figure 2. The results indicate that participants felt more likely to use the robot when it expressed a positive emotion (*joyful* and *surprised*) while stating that they were the least likely to use the robot expressing the *angry* mode.

To compare the likelihood of usage of all expressions, a Friedman test was conducted: $\chi^2(5) = 18.71, p < .0022$, indicating a significant difference in the usage likelihood between at least two of the expressions. A post-hoc Tukey test, used to compare all pairs of group means, was conducted, revealing significant differences in likelihood of usage between the *joyful* and *angry* expressions as well as the *surprised* and *angry* expressions, see table 2. The findings of the preliminary experiment were deemed satisfactory, as a significant amount of potential users were able to correctly identify the expressions of the robot, thus leading to experiment II.

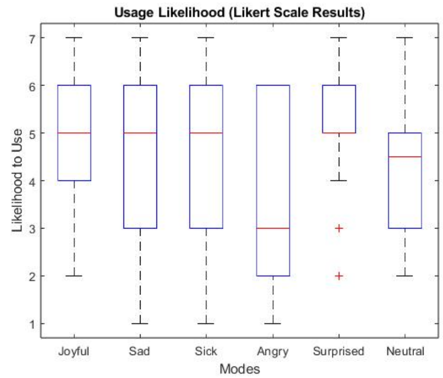

Figure 2: Results of the Likert scale questions about usage likelihood stated in experiment I.

Table 2: Results of the multiple comparison Tukey test. Significant results are presented in bold text.

Appearance 1	Appearance 2	p-value
Angry	**Joyful**	**0.0036**
Sad	Joyful	0.4743
Sad	Angry	0.4272
Sick	Joyful	0.8526
Sick	Angry	0.1301
Sick	Sad	0.9896
Surprised	Joyful	0.9995
Surprised	**Angry**	**0.0117**
Surprised	Sad	0.6907
Surprised	Sick	0.9603
Neutral	Joyful	0.1301
Neutral	Angry	0.8526
Neutral	Sad	0.9828
Neutral	Sick	0.7781
Neutral	Surprised	0.2609

5.2 Experiment II: RIMEPHAS field test

The results of the second experiment are analyzed to determine whether usage is dependent on the expression of the robot. The results of experiment II are shown in Figure 3. The results show that the robot was used most often when showing the *angry* expression, and least when in the *surprised* expression. A Chi Square test of independence was used to determine if the difference between all emotions was significant. The results of this test with $\chi^2(5, N = 600) = 23.17, p < .00027$, confirms this. A pairwise Chi Square test with Bonferroni Correction was used post hoc. The results of the post hoc test are shown in table 3, showing a significant difference between the *angry* and *joyful*, *angry* and *surprised*, and *neutral* and *surprised* modes.

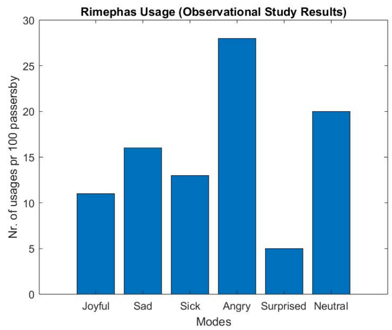

Figure 3: Results of the field study. Each bar represents the number of usages for the respective mode.

Table 3: Results of a pairwise χ^2 test, corrected using the Bonferroni method of observed data.

Appearance 1	Appearance 2	p-value	Bonferroni correction (p<0.0033)
Angry	**Joyful**	**0.0024**	**True**
Sad	Joyful	0.3008	False
Sad	Angry	0.0405	False
Sick	Joyful	0.6634	False
Sick	Angry	0.0086	False
Sick	Sad	0.5469	False
Surprised	Joyful	0.1179	False
Surprised	**Angry**	**$1.1784 \cdot 10^{-4}$**	**True**
Surprised	Sad	0.0112	False
Surprised	Sick	0.0481	False
Neutral	Joyful	0.0787	False
Neutral	Angry	0.1853	False
Neutral	Sad	0.4616	False
Neutral	Sick	0.1824	False
Neutral	**Surprised**	**0.0013**	**True**

6 DISCUSSION

The findings of the study suggest that robots expressing negative emotions influence human behavior, pushing humans toward the action intended with the application. Interestingly, this is against what people state they would do in the questionnaire in Study I (which is, however, in line with much work in HRI that shows mismatches between what people claim they do and what they really do, cf. [10], for instance). A correlation analysis between the liking scores obtained in experiment I and the number of interactions observed in each mode in experiment II reveals a negative correlation between liking and robot use (see Figure 4). Thus, our findings are in line with previous work such that people like robots better that display positive emotions, but they interact more and comply more with the robot that shows negative emotions. Our results shed a novel light on the effects of the relative weight of these two factors in a field trial in a real-life use case.

7 LIMITATIONS AND FUTURE WORK

Limiting the study to a specific location may have limited the generalizability of the findings across diverse settings. Testing different settings may provide insights into how people in different age groups and backgrounds interact with the robot. The interactions are context-dependent as a result of their nature, as people generally want clean hands. Testing multiple other contexts may therefore

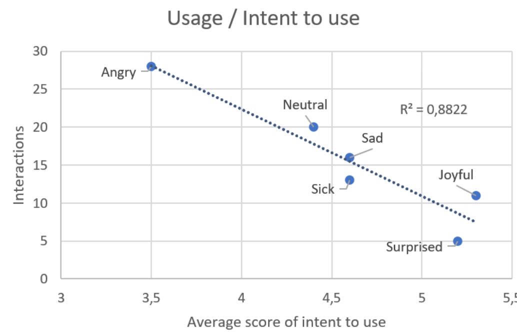

Figure 4: Correlation between the intent to use and actual usage.

provide a more nuanced understanding of the the implications of the context on the results. Observations of the robot often spanned over an hour, revealing fluctuating queue lengths, sometimes extending beyond the placement of the robot. Notably, the users at the end of long queues were more willing to interact with the robot, possibly as a result of boredom or prolonged proximity increasing interest. A placement closer to the theoretical midpoint of the queue may increase the likelihood of usage, as there should always be a user nearby, compared to placing it at the entrance, where there's rarely a queue.
The voice lines differ in length and order of wording between the expressions, reaching the point of the intended action "...sanitize" at different points in the sentence, see figure 1. This may have led to differences in the point in time when the participants heard the call to action when entering the cafeteria, which may have influenced their willingness to respond. In a future experiment, the voice lines should be homogenized in length and structure. As the experiment only spanned a few hours, the samples might not be ideally representative. A suggestion would be to leave the robot for one week, or longer, for each mode, to eliminate sources of error, such as novelty bias. To clearly determine whether the voice, face or a combination of the two is most influential, the different faces and voices should be tested individually, and in different combinations. Furthermore, apart from the differences in emotion expression, the different screens were shown in different colors, which may have influenced the results.

8 CONCLUSION

The results show a significant difference in the number of interactions when the RIMEPHAS robot expressed a negative expression. A sizeable difference in the number of interactions was observed between the *angry* and *surprised*, *angry* and *joyful*, and *neutral* and *surprised* modes of expression, with *angry* and *neutral* being used the most. A future study may allow clarification of limitations such as the positioning of the robot and test duration. Additionally, shedding light on the importance of individual variables of the modes of expression, such as voice lines or facial expressions, may provide a deeper understanding of why users choose to interact with robots showing negative emotions.

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