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Health Promotion, Health Literacy and Vaccine Hesitancy: The Role of Humanoid Robots

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Abstract

The use of humanoid robot technologies within global healthcare settings is rapidly evolving; however, the potential of robots in health promotion and health education is not established. The aim of this study was to explore the impact of a social humanoid robot on individuals' knowledge of influenza (flu) prevention and attitudes towards influenza vaccination. A multi-methods approach involving pre and post-test questions and interviews was used. The study was undertaken in a publicly funded tertiary level hospital in northern Queensland, Australia. Of the 995 participants, the majority were visitors (53.07%). The mean age of the participants was 42.25 (SD=19.54) years. Based on the three knowledge questions that were posed at the two-point interactions of participants with the humanoid robot 'Pepper', the results showed that there was a significant difference in the correct responses pre- and post-test regarding the best way to avoid getting the flu (Exact McNemar significance probability <.0001), how long the flu virus can live outside the human body (p <.0001) and the length of time for handwashing to be effective against spreading germs (p <.0001). The results also showed that there was a significant difference in attitudes associated with influenza vaccination when pre-test was compared to post-test (p=.0019). Interaction of the participants with the humanoid robot demonstrated immediate knowledge gains and attitudinal change that suggests that humanoid robots may be an important intervention for health promotion in prevention of influenza and other respiratory viruses.

Keywords

health promotion, health literacy, robotics, infection prevention, influenza

What do We Know About This Topic?

There has been a significant uptake of humanoid robot technologies in healthcare over recent years.

How Does Your Research Contribute to the Field?

This is the first study to demonstrate the impact of a humanoid robot on improving health literacy in an acute hospital environment.

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What are your researcher's implication to theory, practice or policy?

This study provides evidence for the potential of humanoid robots to be used to provide health promotion and develop health literacy.

Introduction

The use of humanoid robot technologies within healthcare settings has gained traction and is rapidly evolving.[1,2] Humanoid robots are intricate mechatronic systems[3] with human-like physical attributes and inbuilt programming algorithm capabilities that enable them to perform activities such as communicating and interpreting information[4].

There are two important components of humanoid robots that enable them to engage and perform certain activities within the human environment. These two components are sensors and actuators.[5] The key elements of the sensory system include auditory, visual, kinaesthetic, vestibular and tactile senses.[5] The actuator system consists of motors that are responsible for the motion and movement of the robots.[5] The systems and other associated components give social humanoid robots the capability to hear, speak, move, detect motion, display facial expressions and with touch sensors in the head, hands, chest, and legs, detect pressure. Leveraging these social and affective attributes, humanoid robots can engage, influence, instruct, educate, provide assistance, facilitate communication, monitor performance and improve adherence to health treatment.[6] Because of these attributes, humanoid robots are currently used in diverse ways within healthcare settings. For example, humanoid robots assist nurses in taking blood samples, and in the lifting of patients.[7] Humanoid robots are also helping with taking vital signs and delivering meals and medicines.[8] Despite the use of humanoid robots in medical interventions, treatment and care, there is scarce evidence of the use of humanoid robots for health promotion.

Health promotion for the prevention of infectious diseases, such as influenza and Severe acute respiratory syndrome coronavirus-2 (COVID-19), is an area of potential utility for social humanoid robots but to date, this area is under-researched. Seasonal influenza epitomises a perennial disease burden.[9] It triggers illnesses that range in severity and can lead to hospitalisation and death.[9] Globally, an estimated 291 243 to 645 832 seasonal influenza-associated respiratory deaths (4.0–8.8 per 100 000 individuals) occur every year.[10]

In Australia, the highest number of influenza cases were diagnosed in 2019.[11] Between April and September of that year, there were 3732 hospital admissions due to influenza and, of those, 237 (6.4%) were admitted to an intensive care unit.[11] With regards to mortality, between 1997 and 2016, influenza caused 2316 deaths in Australia[12] with 745 deaths in 2017[11] and 705 deaths in 2019[11].

There are a variety of strategies, including vaccination, that can be employed to prevent influenza. The ability of inoculations to prevent illness, disability and death from vaccine-preventable diseases is scientifically established.[13] Yet globally many people, including some health care workers, continue to question the scientific evidence and reject vaccinations.[13,14] Despite the offer of free vaccination for the prevention of influenza, research demonstrates that voluntary vaccination rates among Australian healthcare workers regularly falls below 50%.[15] Vaccine hesitancy is the rejection or postponement of vaccination.[16] In a study to assess vaccine hesitancy among general practitioners (GPs) in France, about 43% of the surveyed GPs were not recommending vaccination to their target patients, which was considered a proxy for the GPs' own vaccine hesitancy. This behavioural phenomenon is context and disease specific.[16] The behaviour is associated with an intricate decision-making process that is influenced by factors such as language and low health literacy,[17] beliefs, attitudes about health and disease prevention, health system and providers, trust and personal experience and perception of the pharmaceutical industry.[16] Other factors include misinformation,[18] disinformation and an emotional anti-vaccination stance.[19]

Our research team were interested in exploring the impact of a social humanoid robot on individuals' knowledge of the prevention of influenza and attitudes towards the influenza vaccination, in an acute hospital setting. The objectives of this study were to: measure the effectiveness of a social humanoid robot to impart knowledge regarding influenza prevention to patients, visitors and staff; assess change in people's attitudes to influenza vaccination associated with an interaction with a social humanoid robot and; evaluate the acceptability and utility of the robot to patients, visitors and staff as a health literacy tool.

Methods

A multi-methods approach involving pre-test/post-test of participant responses to questions posed by a robot and interviews was used. Naturalistic Inquiry[20] guided the interviews noting: the phenomena was studied in the acute health setting, without reference to a priori theoretical approaches, and the researchers had no investment in the findings. This approach ensured that multiple perspectives of the impact of a robot in the healthcare environment were captured.

Setting and the Robot

The study was undertaken in a publicly funded tertiary level hospital in northern Queensland Australia. The robot was situated in the busy corridor leading from the hospital's main entrance to other areas of the hospital. The robot was slightly separated from the normal foot traffic by its placement between two pillars, against a large display wall.

The social humanoid, Pepper (SoftBank Robotics), was leased from ST Solutions Australia by the Townsville Hospital and Health Service. Pepper has a height of 1.2 m, weighs

28 kg, and is powered by a lithium-ion battery that lasts 12 h. For this study, initiation with participants occurred with Pepper being programmed to verbalise a series of questions. These questions were tested extensively during and after programming Participants responded by touching one of four response options on the touch display screen on the robot's chest. Pepper would then verbalise affirmation in the event of a correct response or indicate the response was incorrect and provide the correct information.

Participants

The pre/post-test questions and interviews involved patients, visitors and staff at the hospital as participants. Individuals were informed of the study by promotional materials (a retractable banner, wall posters) and potential participants were provided with a Participant Information Sheet and verbal information from the Research Assistant (RA) who was in attendance with Pepper at all times. Convenience sampling was used for interactions with the robot. The RA(1) screened potential participants and confirmed that they were at least 18 years of age; if between 10 and 17 years of age the RA sought consent from their parent/carer/responsible adult. Children aged younger than 10 years were excluded. Individuals were also excluded if they had participated in this study previously. Verbal consent to participate was obtained prior to data collection.

Data Collection

Data were collected for approximately 280 h over a 12−week period in the last quarter of 2018. Participation in the study entailed a short (less than 5 min) educational interaction with the robot, that included pre-test/post-test questions about prevention of the spread of influenza, and attitudes toward influenza vaccination. The knowledge questions related to the best way to avoid getting the flu, how long the flu virus can live outside the human body, and the length of time for handwashing to be effective against spreading germs. These items and one question relating to attitudes were the repeated measures. All responses to questions on the pre and post-test were logged by the robot. The RA(2) was in attendance to provide oversight and quality assurance; the matching of the responses to facilitate paired pre-post analysis was achieved through computer programming.

A subset of participants who interacted with Pepper was purposively sampled and invited to participate in a brief conversational interview following the post-test. The sample was selected to include a range of ages and hospital categories (patients, visitors and staff) and was unaffected by responses as the interviewer was distant from Pepper and unaware of the logged results. Where groups of people presented, only one of the group was asked to participate.

A semi-structured interview guide was pre-tested with four non-participants and included questions about the motivation of why participants interacted with Pepper, and if they experienced any emotions when interacting with Pepper. Participants were also asked if they were able to understand the information Pepper provided, whether the amount of information provided was adequate, and the quality of the information provided compared to other sources of information such as television, Internet, Apps or health professionals. Participants were also asked if they could identify other potential uses for social humanoid robots in hospitals and health services and what concerns they may have about that use. Participants were advised that the interviews would take less than 10 min. Verbal consent was obtained prior to the interview and included consent for the interview to be audio recorded. Audio files of interviews were transcribed verbatim by a RA. Member checking was not undertaken and data was collected until data saturation was achieved. The study was approved by the health service's Human Research Ethics Committee (THHS HREC/18/QTHS/93).

Table 1. Category of Participants.

Participant type	Frequency (n)	Percent (%)
Visitor	528	53.07
Patient	207	20.80
Nurse	76	7.64
Student	30	3.02
Doctor	24	2.41
Other	130	13.07

Data Analysis

Quantitative data from responses to items posed by Pepper were analysed descriptively (frequencies, percentages, means and standard deviations) using Microsoft Excel and StataSE (v16). Each question was coded as a dichotomous 'Correct' or 'Not Correct'. To test whether there was a difference in the 'correct' responses in the pre-test compared to the post-test, McNemar's test was used,[21] p.384 Statistical significance was set as $P < .05$. Thematic analysis of the transcribed interview data was conducted using an established method for qualitative analysis.[22] Initially, familiarisation of the data occurred by reading through the verbatim transcribed files. Interview transcripts were coded by a letter (V = visitor, P =patient, N = nurse, S =student, D =doctor) and number to note their classification and the chronological order of their interview. Transcripts were read and re-read by two researchers (OO &WS), who identified sub-themes and themes. A third researcher (CN) was available to resolve discrepancies but was not required. Identified themes were reviewed and refined by the research team.

Results

Patients, visitors, nurses, students and doctors interacted with Pepper (n = 995), with just over half of the participants being visitors to the hospital (n = 528, 53.07%) Table 1. The dataset

Table 2. Difference in the Correct Responses in the Pre and Post-Tests.

Question	Pre-test correct, %	Post-test correct
What is the best way to avoid getting the flu? (Correct answer – vaccination)	45.3	90%[a]
How long can the flu virus live outside the human body? (Correct answer – Hours)	23.9	85.5%[a]
How long should you spend washing your hands to be effective against spreading germs? (Correct answer – 20 seconds)	45.7	91.1%[a]

[a]Approximate. (Exact McNemar significance probability = <.0001)

Table 3. Reasons Cited for Not Being Vaccinated.

Reasons	Frequency	Percentage (%)
Feels fit and healthy		
Yes	150	45.73
No	178	54.27
Thinks will recover quickly		
Yes	131	39.94
No	197	60.06
Concerned about getting the flu		
Yes	114	34.76
No	214	65.24
Concerned about side effects of vaccination		
Yes	119	36.28
No	209	63.72

Table 4. Themes and Sub-Themes Arising from the Interviews.

Theme	Sub-theme
Robots provide quality, trustworthy information	Trusted information
	The right amount of information was clearly presented
	Interaction was informative
	Preferred source of health information
Robots are engaging	Interactive
	Positive emotions
	Admiration for the robot
	Future uses

was complete with a response required for each question. No participant withdrew from the study. The median age of the participants was 42.25 (IQR 19.54) years. The youngest participant was 10 and the eldest was 90 years.

There were statistically significant improvements in responses to the three knowledge questions in the post-test Table 2. When the participants were asked to respond to the importance of having an influenza vaccination at pre-test 93.97% either strongly agreed or agreed that influenza vaccination was important; post-test 96.08% either strongly agreed or agreed that the influenza vaccination is important. This difference in attitudes towards influenza vaccination was statistically significant (Exact McNemar significance probability = .0019).

However, when the participants were asked if they had been vaccinated against flu that year, one-third (n = 328, 33%) responded 'No'. Almost half of those 328 participants responded that they were not vaccinated because they felt fit and healthy. Responses to other reasons for not being vaccinated are included in Table 3.

When analysing the data for the visitor sub-group (n = 528), the results were equally compelling for knowledge gain with the proportion of correct results doubling or tripling following the interaction with Pepper. Identification of vaccination as the most effective method to prevent influenza increased from 43.75% (231/528) (pre-test) to 89.96% (475/528) (post-test); the correct response to viability of influenza outside of the human body increased from 22.16% (117/528) (pre-test) to 86.36%(456/528) (post-test); and the correct response for effective handwashing time increased from 43.37% (229/528) (pre-test) to 90.15% (476/528) (post-test).

An overwhelming majority (99.2%) of all participants enjoyed meeting with Pepper.

With respect to the qualitative data, 35 interviews were undertaken and two core themes (each with four sub-themes) were identified: (1) The robot provides quality, trustworthy information and (2) Robots are engaging. Sub-themes are outlined in Table 4. No participant withdrew from the interviews.

Qualitative theme 1: The robot provides quality, trustworthy information

Interviewees trusted the information provided by Pepper. For example, a visitor said,

> "Pepper's information is …real" and that "robots have good knowledge…and Pepper knows what she is talking about".

Respondents indicated that the amount of information provided by Pepper was appropriate to the task, and it was clearly presented. Although the information provided was acknowledged to be similar to that given by a professional, a mother whose child was hospitalised noted the information to be:

> "more direct…[Pepper] gives you the exact information that you need".

Most of the participants expressed the opinion that their interaction with Pepper was informative. As a doctor remarked:

> " I thought it was fantastic because I am medical trained …I did the flu questions and even though I got them wrong in the first time and the second time and you know so it was very informative."

Participants expressed varying opinions as to whether they preferred interaction with Pepper compared to a health professional or other sources of health information such as television or the internet as a source of health information. A participant, who was accompanying a relative to a hospital appointment, remarked:

> "I think that what Pepper has done now is short and easy for us to understand whereas with the health care professional, they take a long time."

Participants also viewed information received from Pepper and health professionals as the same. As this participant who had an outpatient appointment explained:

> "It's probably the same type of info [compared to doctor and nurse]. It's just the delivery that's different…Maybe better than a doctor."

However, some participants were clear that they preferred consulting with a health professional rather than Pepper for information regarding the prevention of influenza, as exemplified by a parent accompanying their child to an appointment:

> "…the doctors…they have experience with their patients. The robots follow the instruction that they have been given. So the robot has limited information. There is not reaction or emotions. It's just a robot."

Qualitative Theme 2: Robots Are Engaging

Participants described their experiences of how interactive their engagement with Pepper was. As this new staff member explained:

> "…I think in terms of giving fast information in a new and interactive way that grabs people's interaction. I think robots like Pepper can do that very well."

Participants indicated that they experienced positive emotions during their interaction with Pepper. As this nurse remarked:

> "I was quite delighted. I think that the hand movements and the fact that it makes human nuances, you know, gestures and things like that, and I was very delighted… So you actually feel very calm and happy. So yeah that was very good."

Participants also described their admiration for the robot, as the nurse cited above continued to say:

> "The hand movement, particularly the finger movements humanized her a little bit so that goes a long way. It is not just a screen or someone talking to you. The way she was trying to explain things with her hand, I was really impressed."

Based on the interactive and engaging time participants had with Pepper, there were suggestions for future uses of Pepper within the healthcare system. A staff member who also suggested that the hospital get another Pepper, said:

> "I think she can do some health promotions (sic) or healthy eating weight loss."

A mother visiting the hospital with her young son was enthusiastic about her interactions with Pepper and suggested the following future use:

> "Also it would be good for people like the elderly all those who have, long term stay. It would give them some comfort. When they can't have comfort and can't have people around."

Data available upon request to corresponding author subject to ethics approval.

Discussion

A humanoid robot-assisted intervention is a promising and novel innovation that can potentially lead the way in 21st-century health promotion efforts. In this study, there was a significant increase in correct responses in the post-tests compared to baseline in respect of the best way to avoid getting the flu, how long the flu virus can live outside the human body and the length of time for handwashing to be effective against spreading the virus. This finding demonstrates that the interaction with Pepper changed participants' knowledge. Hence, humanoid robots could be effective in terms of knowledge transfer. This is the first study that has demonstrated outcomes in of health promotion and health literacy following interaction between a humanoid robot and a general population sample in an acute health setting.

Health literacy relates to how people understand information about health and health care, and how they apply that information to their lives, use it to make decisions and act on it for the benefit of their health.[23] A systematic review of eHealth interventions to improve health literacy established that traditional methods of interventions to improve health literacy may no longer be effective.[24] A recent study conducted in Australia showed that inadequate health literacy and lower education level were significantly associated with a reluctance to be vaccinated against both influenza and COVID-19.[25] Our study therefore provides evidence of the potential of a humanoid robot to impact health literacy as an alternative tool in enhancing individuals' knowledge about prevention of influenza. As low levels of health literacy have been found to be associated with a lack of intention to get vaccinated against COVID-19,[26] the use of humanoid robot could play an important role in addressing vaccine hesitancy related to poor health literacy in the ongoing COVID-19 pandemic.

Certainly the results of our study demonstrate the value of Pepper with respect to overcoming influenza vaccine hesitancy. The findings from the qualitative arm of this study provide some insights as to how the interaction with Pepper may have influenced the attitudes of the participants; for example, participants expressed overwhelming confidence in the robot to provide credible information. Thus, the changes in attitude that occurred in this study suggest that humanoid robots may be able to play an important role in influencing a positive behavioural change towards influenza vaccination, as well as other illnesses, in the general population. This is because garnering the attention of the population in public health campaigns requires health interventions that are engaging, contain quality information and are considered trustworthy[14,27]. A humanoid robot possesses all these qualities, as evidenced from the analysis of the interviews. However, despite the highly positive attitudes towards vaccination pre-and post-interaction with the robot, a considerable proportion of the participants reported they had not been vaccinated for influenza at the time of response. One explanation for this may be a recall issue; this study was conducted during the late springtime, well after the peak influenza period.

The results from this study demonstrate that almost all the participants enjoyed their interaction with the humanoid robot. Perhaps one of the reasons for the overwhelming acceptability of Pepper by the participants in this study was the readability of information displayed by the robot and the manner in which Pepper presented messages that were easy to understand. The presentation of material devoid of complex concepts that require a certain ability and skill level to interpret is established as an effective strategy.[28] In line with our results, evidence from other studies suggests that a humanoid robot is widely accepted by different groups. Young adults prefer a humanoid robot to provide healthcare assistance in hospital health care,[29] healthcare personnel accept robots as beneficial technology for the provision of psychosocial care for older adults in long term care[30].

The findings from this study have implications for public health and practice. This is because the study provided insights into the possibility of the use of humanoid robots in providing health promotion information related to the prevention of influenza and this may have utility and implications for other respiratory viruses such as COVID-19. However, further research is required to assess if the knowledge gained is sustained and if behaviour changes as a result of interaction with a social humanoid robot.

The strength of this study includes data from responses to items posed by Pepper and interview transcripts, drawn from a large and diverse group of people such as visitors to the hospital, patients, patient relatives and clinicians. Data obtained from this multimethod approach were triangulated to address the project's aim. Thus, this process allowed the synthesis of diverse data sources which added to the richness of the study's findings. A limitation of this study is the inherent limitation of a pre/post-test in establishing causation. Another limitation of this study is the likelihood of social desirability bias which may have influenced some participants' responses to questions about their views on the robot. However, care was taken to design questions that were not leading and assurance regarding anonymity of responses was provided. Finally the limitation of convenience sampling is acknowledged, meaning these result pertain to the sample not the population.

Conclusion

This study has provided insight into the value of a social humanoid robot for improving individuals' knowledge of influenza prevention and changing their attitudes towards influenza vaccination. As a result of the interaction of the participants with the humanoid robot, there were immediate knowledge gains and attitudinal change, indicating that humanoid robots may be an important intervention for health promotion in the area of prevention of influenza. A social humanoid robot was found to be acceptable in an acute hospital setting, with suggestions for expanded uses identified. There is an opportunity to conduct research, such as randomised controlled trials, to establish the effectiveness of a humanoid robot as a vehicle for health promotion against the prevention of respiratory viruses such as influenza and COVID-19.

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Supplemental Material

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