Investigation of Practical Use of Humanoid Robots in Elderly Care Centres

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ABSTRACT

The global trend of population ageing has magnified the shortage of qualified staff in the elderly care industry. This study evaluates the feasibility and user experience of introducing robots in elderly care services. A robot instructor was being benchmarked against a human instructor administering two types of activities with 41 elderly participants. The results show that robot was more effective and better preferred by users over human instructor on instructing physical exercise, while reaching similar level of effectiveness and user acceptance on information delivery. Additionally, user perception of robots improved after the robot experiment session. These findings could be useful for future design of robots for elderly users and for social robots in general.

Author Keywords

Human-robot interaction; social robotics; humanoid robots

INTRODUCTION

Singapore has one of the fastest growing ageing population in the world. Residents aged 65 years and above made up 11 per cent of the resident population in 2014 [9]. Meanwhile, the elderly care landscape in Singapore is far from ideal. One major problem is the shortage of qualified elderly care staff to keep up with the burgeoning demand. This problem is shared by many ageing societies across the globe. Recently, using assistive robot technologies has emerged as a solution [2]. In nursing homes, robots cooperate with caregivers to remind elderly to take medicine, assist elderly on daily activities such as eating and walking [14, 3], encourage social interaction [6] and provide psychological support [13, 12].

It is, however, worth-noting that people's attitude towards robot technologies varies with age [7]. Scopelliti et al found that older people were significantly more suspicious of technology, and showed a more negative emotional response towards robots [11]. A closer examination is hence needed on user acceptance when designing robots for the elderly [4, 5]. In other word, how should assistive robots be designed and used so that they are better welcomed by elderly users, and what are the tasks that robots are most useful for when used in elder care?

Current studies on robotics for the elderly have mostly focused on system functionalities or user perception alone [10, 14, 8]. Little attention is paid on comparing robots with its human counterparts, whom the robots will ultimately be employed to assist and relieve. In this work, we benchmark a robot against a human instructor performing similar tasks with groups of senior citizens. In our approach, a humanoid robot is used to instruct groups of elderly on simple physical exercises and to teach them factual information. The robot's performance is then compared against that of the human instructor under a similar controlled setting, through a series of analyses of the participants' responses.

HYPOTHESES

Six hypotheses were established for this study.

Hypothesis 1: Robot instructor is objectively more effective than human on instructing physical exercise.

Hypothesis 2: Human instructor is objectively more effective than robot when delivering factual information.

Hypothesis 3: Participants evaluate robots more positively after than before the robot-instructed session.

Hypothesis 4: Participants evaluate the robot instructor as more suitable for instructing the physical exercise than delivering factual content.

Hypothesis 5: Participants report a clear preference for the robot instructor over human on instructing physical exercise when asked to directly compare the two instructors.

Hypothesis 6: Participants report a clear preference for the human instructor over robot on delivering factual information when asked to directly compare the two instructors.

METHODOLOGY

We use control experiment to compare the robot instructor with the human instructor on two types of activities. There are two within-subject factors: instructor (robot, human) and instruction content (physical activity, factual information). Participants are instructed on the two types of content by both robot and human, one after the other. The order of the instructors is counterbalanced among the participants. Each instructor engages the participants for 15 min. Mandarin, the participants' mother tongue, is used throughout this experiment.

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Instructors

Robot instructor

Aldebaran NAO, a 58cm-tall humanoid robot was used. Its movements and speech are preprogrammed on a time-line using Choregraphe SDK. The robot uses audio recording of the human instructor as its "voice". This avoids confusion caused by the robot's accent and eliminates bias due to participants' voice preference. NAO is set on its Autonomous Life mode, by which it identifies and gazes at human faces within its visual range, mimicking the natural eye contact of a human speaker with the audience.

Human instructor

The human instructor is a staff member from Lions Home for the Elders. No participants knows the instructor personally prior to the experiment. During the physical activity coaching, the human instructor follows approximately the same pace as the robot and is instructed not to adjust her pace according to the participants'. The instructor strictly follows the script set for her and the robot. Both instructor remain standing in one place throughout the period of instruction. Apart from natural eye contact and hand waving, she does not make extra movements to attract attention. These restrictions ensures that the differences are only on delivery media and content, but not on delivery style.

Instruction Content

Physical activity

The instructors conduct demonstration on simple joint exercise and ask participants to follow the exercise. The exercise is adapted from a set of exercises provided by Pek Kio Community Centre senior living programme, consisting of 5 movement sets. All movements are easy-to-follow, minimizing the effect of familiarity on execution accuracy. Both instructors count the beats aloud while demonstrating.

Factual information

The instructors deliver facts and healthy living tips related to common health problems such as diabetes, coronary heart disease and dementia to the participants. Each instructor delivers a different set of information so as not to reinforce memory of the same content in the second session. Both sets of information are about 300 words.

EXPERIMENTS

Survey data is collected before, in-between and after the two sessions. Two aspects, effectiveness and participant evaluation of the two instructors, are measured and compared. Additionally, elderly users' evaluation of the robot before and after the experiment is also studied.

Objective evaluation of effectiveness

Physical Exercise

To examine the effectiveness of the physical exercise, we use two criteria set by the elderly care centre to evaluate the performance and compliance in all the exercise sets:

Joint bending (J): Whether the participants reach the desired level of joint bending specified in the exercise description provided by the centre on each beat.

Movement sync (V): Whether the participants are able to sync the exact speed of their movements to the instructor on each count. The maximum beat count difference allowed is two counts, i.e. a participant fails to sync on a particular count, if he or she is in a position two counts ahead or behind.

We analyse the performance of participants in the exercise by observing the video recording of the experiment. Each participant is judged on both criteria over $5 \times 32 = 160$ beat counts, and receives two performance scores: Joint bending (J) and Movement sync (V). The highest score for both criteria is 160. One mark is deducted from the respective highest score for each count the participant fails to meet the aforementioned criteria. Each participant also receives a total score (T) calculated as J+V.

Factual information

To assess the effectiveness of factual information delivery, a set of 8-item choice recognition test is given to participants immediately after the factual content is delivered by each instructor. Each item asks the participant to determine whether a statement has been presented during the session. There are 8 statements for each instructor, 4 that occurs and 4 otherwise. This reflects the attention level paid to the instructor.

Evaluation of the robot

General perception of robot is measured both before and after the two sessions, based on participants' responses to ten five-point semantic differential scales (1 and 5 denote that the robot is best described by the negative and positive adjectives respectively) concerning the following robot descriptions: unfriendly/friendly; dangerous/safe; rigid/natural; vague/distinct; inaccessible/accessible; empty/full; dull/exciting; cold/warm; passive/active; unintelligent/intelligent. Participants are also asked to choose their preferred robot instructed content (physical exercise v.s. factual information delivery).

Direct comparison

Additional questions ask participants to directly compare the two instructors, to understand the participants' preferences. On each type of instructed content, participants are asked to choose the one they like more and feel that is more effective between the robot and human instructor.

RESULTS

A total of 41 elderly from Lions Home for the Elderand Pek Kio Community Centre senior living programme sparticipated had completed the experiment. There were 25 female participants (61%) and 16 male participants (39%). Participants' age ranged from 67 to 86 (M=73, S.D.=4.84). Half of the participants (n=20) were instructed by the human first, the other half (n=21) were instructed by the robot first.

Objective evaluation of effectiveness results

Paired samples t-test was used to compare the data collected from objective evaluation of effectiveness of two instructors. In support of hypothesis 1, the physical exercise instructed by robot was significantly more effective than that of human instructor (Figure 1). The average total score (T)

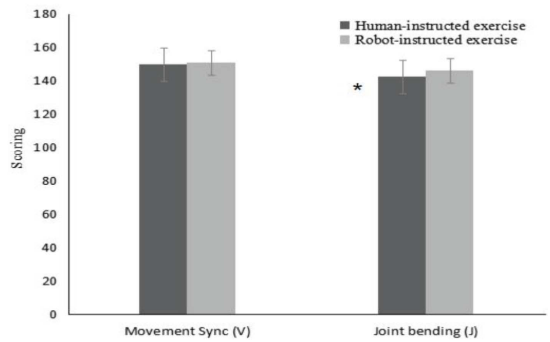

Figure 1. Results of objective effectiveness of physical exercise conducted by human and robot instructors. Significant difference is marked by asterisks (*).

for each participant during robot-instructed physical exercise (M=297, SD=10.9) was significantly higher than during human-instructed physical exercise(M=291, SD=14.4); t(40)=2.52, p <.05. Though J under robot-instructed condition was significantly higher than under human-instructed condition, V under robot-instructed condition was only somewhat significantly higher than under human-instructed condition. The robot's main strength was its ability to motivate participants to reach the desired level of joint bending.

The effectiveness of factual content delivery showed no significant difference between the two instructors. Average number of correct answers under robot instruction (M=6.88, SD=1.14) was similar to that under human instruction (M=6.90, SD=1.02); t(40)=0.0835, p¿.10. Hence, hypothesis 2 was not supported by the result. The robot and human instructor were about equally effective when delivering factual information.

Evaluation of robot results

Table 1. Participants' evaluation of the robot on 5-point semantic differential scales before and after the instruction session with robot

Adjective pair	Before	After
Unfriendly / Friendly	4.17	4.33
Dangerous / Safe	3.34	4.27
Rigid / Natural	3.56	3.83
Vague / Distinct	3.37	3.46
Inaccessible / Accessible	4.07	4.34
Empty / Full	3.88	4.07
Dull / Exciting	4.12	4.27
Cold / Warm	3.34	3.98
Passive / Active	4.00	4.20
Unintelligent / Intelligent	4.63	4.37
Mean	3.85	4.11

Participants' perception of robots enhanced after the robot-instructed session, supporting hypothesis 3. The average score on the five-point semantic differential scales of the ten adjective pairs increased towards the positive end (from M=3.85 before, to M=4.11 after) as shown in Table 1. Scale that demonstrated greatest level of improvements were dangerous/safe (from M=3.34 before to M= 4.27 after).

Participants rated the robot as more suitable for instructing physical activity than delivering factual information, supporting hypothesis 4. More participants reported that the robot-instructed physical activity was more enjoyable (n=35, 85.4%), useful (n=24, 58.5%) and they were more willing to accept a robot instructor for physical exercise in future(n=31, 75.6%) than for factual information delivery.

Direct comparison results

Table 2. Participant responses to items for direct comparison of the robot and human instructors

Description	Human	Robot	Equally
Liked more for physical activity	0(0%)	38(92.7%)	3(7.3%)
More effective for physical activity	7(17.1%)	8(19.5%)	26(63.4%)
Liked more for information delivery	6(14.6%)	17(41.4%)	18(44.0%)
More effective for information delivery	7(17.1%)	4(9.8%)	30(73.2%)

The results of direct comparison of human and robot instructors supported hypothesis 5. Participants demonstrated a strong preference for the robot instructor over the human instructor on instructing physical exercise (Table 2). Specifically, majority (92.7%) of the participants reported they liked the robot instructor when doing physical activity more than the human instructor, while the remaining 7.3% all viewed the two as equally likeable. On subjective effectiveness, the robot instructor received a slightly higher vote (19.5%) than robot instructor (17.1%).

Hypothesis 6 was not well-supported by the direct comparison results. For information delivery, participants also seemed to prefer the robot instructor (Table 2). Only 14.6% participants liked human instructor more, compared to the 41.4% for robot instructor. On subjective effectiveness, majority (73.2%) of the participants felt both were equally effective. 17.1% participants felt the human was more effective, higher than the 9.8% of the robot. Although the human instructor were perceived as more effective, participants still had a strong inclination towards the robot instructor as agent for information delivery.

DISCUSSIONS

The result of the study showed the robot instructor was more suitable for physical activity instruction than information delivery, both in terms of objective effectiveness and subjective evaluation. Countering hypotheses 2 and 6, the robot was not significantly less effective or less preferred than the human instructor for information delivery. In fact, it reached similar level of objective effectiveness as human instructor, and was even liked by more participants for this purpose. Additionally, participants' perception of robots in general improved after the robot-conducted session.

Countering the overall perception improvement, participants seemed to perceive robots as slightly less intelligent after(M=4.36) the session than before (M=4.63). One explanation for the decreased rating of robot intelligent might be that the session content was rather repetitive and predictable, and the robot did not actively interact with the participants during the session. According to [1], predictability and lack of interaction make agents appear less intelligent. However, the same study pointed that predictability also potentially makes agents appear less frightening for inexperienced users. This may also explain why participants generally perceived robots as safer and more friendly after the session.

However, it is worth noting that the human instructor was under various restrictions for variable control purpose. Further studies can use higher level of audience engagement techniques to reassess the effectiveness of a robot speaker with respect to a human speaker. Also, despite the effort of ensuring the robot and human had the same instruction style, humanoid robot was still a novel occurrence for most elderly. Novelty may potentially enhance participants' subjective rating of the robot. To further investigate the novelty factor, future studies should use the robot to facilitate activities over a prolonged period, such as one year. Objective effectiveness test and user perception evaluation are to be conducted consistently throughout the course of the year, to minimize novelty level.

CONCLUSION

Based on the results of the study, we concluded that humanoid robots have great potential as agents for exercise coaching and information delivery for elderly users. It was encouraging to see that the robot could motivate the elderly to do exercises effectively better than the human instructor, while still having the same level of effectiveness on information delivery. Overall, it remains a challenging task to explore the design principles of robots meant for elderly users, to achieve the goal of letting robots share and reduce the workload of humans in elderly care services.

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