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A Humanoid Social Robot to Provide Personalized Feedback for Health Promotion in Diet, Physical Activity, Alcohol and Cigarette Use: A Health Clinic Trial

Nicole L. Robinson¹, Jennifer Connolly², Gavin Suddrey³ Madeliene Turner⁴ and David J. Kavanagh²

Abstract—Social robots have been used to promote health education and coaching to provide health information. Important behaviors to address and monitor include actions that can be modified, such as physical activity. These behaviours often require different personalised recommendations. Robots could be an effective way to give personalised health feedback based on scores, including in acute medical settings. This trial involved an automated social robot interaction in a health clinic to collect health data and provide personalized feedback on four key factors: exercise, diet, alcohol and cigarette use. Patients completed an 20-minute health questionnaire with a Pepper Robot in a clinic room during a health visit. The interaction was programmed to run autonomously with automatic scoring and feedback based on health scores. Instructions were delivered using co-verbal speech and detailed text on the tablet. Questions also included ratings on comfort to discuss health topics with a human or robot. Patients could choose to receive an optional follow-up in four weeks' time. A total of 47 patients completed the session. Patients reported being as comfortable to discuss health-related topics with a robot or human for exercise, diet, alcohol, cigarette use, and mental health. Program evaluation received moderate ratings for the robot on ease of use, usefulness and motivation to change a health behavior. No significant health changes were found 30 days later due to high initial health scores, leaving little room for improvement. This initial proof-of-concept trial found that a robot-delivered service could be deployed in a live health clinic in conjunction with patient visits.

I. INTRODUCTION

Social robots provide a novel, engaging, accessible and automated platform for data collection and health education. A brief health assessment can be beneficial to patients by providing rapid insight into health-related behaviors. This includes bringing awareness to actions that can influence health outcomes, such as levels of physical activity or volume of alcohol consumed on a weekly basis [1]. Self-assessment feedback can help to prompt health-related discussion during

a clinical appointment, acting as an initial starting point during a clinic visit to receive recommendations and suggestions. This can be important, especially for people who do not meet recommended health guidelines, e.g. [2]. Social robots have already been demonstrated to collect health measures for data administration [3] and to provide a health status survey [4]. Social robots that provide health education and personalised feedback can be paired with health services, such as while waiting for a clinical appointment – a wait time that can often be 20 to 40 minutes or more [5]. This service could help to assist doctor and nurse workload during brief clinic visits, by providing health information and data collection services [6], [7]. Social robots as an automated service could become an important health prevention and low intensity-intervention tool to promote healthy lifestyles.

A. Social Robots and Health Behavior

Social robots have provided support to health tasks, including to promote daily health behaviors for a healthy lifestyle. Social robots have taken on different roles in healthcare services, including as an information point, tool to assist in healthcare, and as a health coach [8], [9], [10]. Social robots have led exercise sessions for children to perform physical activity [11], encouragement to adults to perform exercise [12], and motivational support to help increase physical activity [10], [13]. Social robots have also been used to as an automated health coach to encourage healthy eating patterns [9], [14], including a multi-session program to improve diet and weight reduction [14]. These sessions have provided healthcare support with a focus on longer program delivery rather than brief individual, customised feedback. In addition, few health trials have been conducted directly in acute healthcare settings, such as a health clinic, in which people could benefit from access to brief healthcare programs [8], [15]. This collection of research shows that social robots can coach people to think and act on health behaviour change, and those actions are later performed after the session has ended. Social robots can therefore have some positive influence on helping people to make changes to their health.

B. Background - Daily Health-Related Behavior

To support health behaviour change, it is important to select key health factors that should be addressed in a robot-delivered session for a health clinic. The World Health Organization has identified and recommends the management

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of four daily behaviors (i.e. modifiable risk factors) for improved health outcomes: physical activity, dietary intake, alcohol and cigarette use [16], [2]. Routine reduction of these modifiable risk factors is vital for the prevention, delay and management of non-communicable diseases (NCDs), which accounts for around 70% of deaths worldwide [16]. For instance, physical inactivity affects around 1 in 4 adults [2] and poor dietary intake contributes to millions of global deaths per year [16], [17]. Alcohol use levels for volume alcohol has increased by 70% in the last 30 years [18] and tobacco is still used by around one billion people [19]. These four daily lifestyle behaviors can lead to other health outcomes and contribute to total disability-adjusted life years [20]. Daily management and routine practice can also have positive long-term influence on other diseases [21]. General information and brief personalized interventions can also create some modest changes on daily behaviors, e.g. [1]. Health factors for physical activity, dietary intake, alcohol and cigarette use, paired with the provision of education and personalized feedback may have some impact as a low-intensity health promotion program.

C. Study Aim and Hypothesis

A social robot to collect data on the four modifiable risk factors and provision of detailed feedback integrated in a live health clinic had not been explored. This feasibility study aimed to investigate the utility of a social robot in a health clinic setting. The robot interaction was designed to assess four key modifiable risk behaviors and give personalized feedback relative to recommended guidelines, given their importance for the prevention of NCDs. The robot was chosen to present an informative, collaborative, and encouragement to patients to provide honest and accurate feedback to their health questionnaires. This included providing both verbal and text instructions to guide people through how to enter their health data for scoring. Both patients and health practitioners were recruited, but only patient data will be reported. It was hypothesized that patients would evaluate the session as helpful, and the robot service would autonomously operate in a clinic without significant difficulties, or the need for research staff to intervene, representing a value proposition to the clinic. After completion, this study would provide a basis for future deployments, such as extended trials and more complex designs.

II. METHOD

A. Robot Interaction

1) *Robot*: The Pepper Humanoid Robot by SoftBank Robotics delivered the interaction [22]. The Pepper Robot had the NAOqi 2.5.5 OS installation, ASUS Xtion 3D system-on-a-chip (SOC) image sensor, tactile sensors on the head and hands, two speakers, and two 2D cameras (OV5640, 5Mp SoC CMOS image sensor). The robot has a 10.1-inch LG CNS tablet (175mm height, 246mm width, 14.5mm depth) attached to the chest.

2) *Interaction Design*: The interaction involved a predefined interaction script using a HTML/Javascript service run through the Choregraphe programming environment [23]. It involved guiding people through self-report health questionnaires in a set order. The interaction used available software packages compatible with the NAOqi OS (i.e. ALAnimatedSpeech, ALTextToSpeech, ALFaceTracker, ALAutonomousLife) so the session could later be deployed in other health clinics with minimal technical effort. Autonomous life mode was used for the robot to appear more animated when providing verbal instructions. This function was paused when people were asked to give data on the tablet so that minor movements did not make it difficult to enter data. Face tracking was used to ensure the robot maintained eye contact when providing instructions. The robot was programmed to use co-verbal gestures when talking through instructions, which were pre-selected for each segment to ensure that open and supportive gestures were used to encourage participation. Verbal speech modifications were not made, using the available text-to-speech with the robotic platform. Participants were able to control the flow of the interaction by using buttons to indicate when they had finished completing the questionnaire set. Participants gave consent on the tablet and completed a short tutorial (i.e. a button, textbox and slider) to help screen out people with English difficulties or with following instructions.

Data collection involved entering responses on the tablet. The robot provided both verbal and text-based instructions on how to complete each question set. Spoken phrases to collect health data were not used as initial testing found they were difficult to use with non-technical users, which would have required a longer instruction period, impacting ease of use and session time for them. This feature design could have also created some challenges given that an error could have had detrimental effects on scoring and subsequent health recommendations. Health questionnaires were built using text, radio, check and textbox elements. Participants were required to complete each question so no missing data was present for the final feedback sheet. The customised feedback sheet provided different health recommendations or statements based on calculation scoring from each health questionnaire set. Patients could see their feedback scores on the tablet based on their responses to the health questions. For example, low exercise levels meant that the robot provided a statement about increased health risk, whereas high exercise levels involved the robot providing praise for their current physical activity levels. Examples of the questionnaires can be seen in Figure 1. Further information and feedback sheet examples can be seen at: https://bitbucket.org/pepper_qut/health_assessment/src/master/

Responses were stored as de-identified JSON. Participants had the option to send their feedback scores to a printer located in the same room. The printing module accepted user entered data in JSON format, computed relevant scores for the health components, and inserted scores into a HTML template file. The outputted HTML was sent over the network to a simple web server that would convert the received

These questions are about your use of cigarettes.

On what day did you last use tobacco?

(mm-dd-yyyy)

How many cigarettes did you have on that day?

How comfortable would you feel talking to a robot about the following topics?

	0 = Not at all	1	2	3	4	5	6	7	8	9	10 = Extremely comfortable
Casual conversation	☐	☐	☐	☐	☐	☐	☐	☐	☐	☒	☐
Physical exercise	☐	☐	☐	☐	☐	☐	☐	☐	☐	☒	☐
Dietary intake	☐	☐	☐	☐	☐	☐	☐	☐	☐	☒	☐
Alcohol use	☐	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
Smoking	☐	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
Mental health	☐	☐	☐	☐	☐	☐	☐	☐	☒	☐	☐

Fig. 1: Example of the Tablet Interface Screens

HTML into a PDF document to send to a network-connected printer. Email addresses were stored in a separate secure file to uphold confidentiality. Session time was calculated from the first button press to confirming the end of the session. The interaction underwent extensive testing, including a match of a digital and paper questionnaire to ensure accuracy in data collection and storage. The robot interaction was designed to run autonomously with minimal involvement for clinic staff. Clinic staff roles included turning the robot on/off during work hours, setting up the testing room and launching the program from the tablet interface.

B. Procedure

Participants needed to be at least 17 years of age and patients of a university-based allied health clinic. English fluency was required for independent completion of the assessment and interpretation of the feedback. Recruitment occurred over 67 days using self-selection after reading an information sheet or after receiving information from reception staff. Recruitment methods were simplified and minimal to explore how an autonomous robot would integrate in a health clinic without external involvement or allocated staff to operate it, representing a more realistic autonomous deployment. Participants were invited to complete the trial during their visit, but they could return at a later date.

Participants were shown to a private testing room by clinic staff and left to complete the session on their own. Measures were completed in a set order: demographics, physical activity, diet, alcohol use, cigarette use, and comfort to discuss health topics. Personalized feedback was presented on the tablet, and individuals could choose to receive a print out of their feedback sheet. All were given the chance to enter a prize draw to compensate them for their time (\$100 VISA card). At the end of the robot interaction, patients were invited to receive a follow-up survey in 1 months' time at the end of the robot interaction. To encourage participation in follow-up, there was an option to enter a second prize draw (\$50 VISA card) on follow-up completion. Follow-up

was optional to reduce initial commitment burden. The trial setting can be seen in Figure 2.

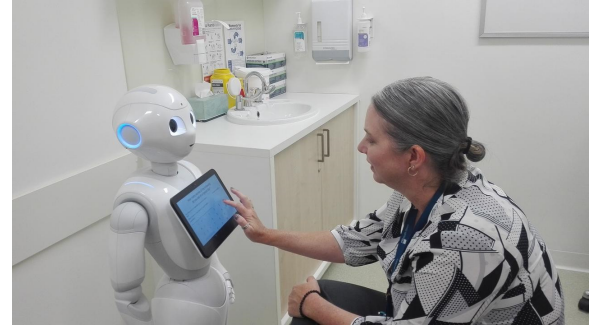


Fig. 2: Experimental Setup

C. Measures

Questionnaires, including item sets, scoring and feedback sheet statements, can be seen in detail at: https://bitbucket.org/pepper_qut/health_assessment/src/master/

1) *Demographics*: Data included age, gender, occupation area, relationship status, completed level of education, if they were a university student and study field, experience level with technology, robotics, and programming/coding.

2) *Program and Robot Evaluation Questionnaire (Patient Follow-up)*: This 7-item questionnaire was created to evaluate the program and the robot that delivered it. Questions included: 1) Did you give the questionnaire sheet to your health practitioner during your appointment? 2) How easy was it for you to do the health questionnaire with the robot? 3) How useful was it to complete the questionnaire before your appointment? 4) How much more motivated are you to change a health behavior after doing the questionnaire and talking to your practitioner? 5) After this experience, how much more do you want to improve your: Diet, Physical Activity, Drinking, Smoking 6) What was it like to do the health questionnaire with the robot? and 7) How did you feel about giving the summary sheet to your practitioner?

3) *Robot and Human Clinician Health Topic Questionnaire (HQ)*: A 12-item custom-made question set to assess how comfortable people would feel talking a robot (HQ-R) or human (HQ-H) as the conversation partner for the following topics: casual conversation, physical exercise, dietary intake, alcohol use, smoking, and mental health.

4) *Robot Incentives, Self-Efficacy and Usage Intention (Patient Follow-up)*: The Robot Incentives Scale (RIS) is a 12-item questionnaire to measure incentives to interact with a social robot [24]. The 11-item Robot Self-Efficacy Scale (RSES) [24] measured confidence to interact with the robot. Willingness to Use involved a short series of questions about intention to use the robot.

5) *Health Measures*: The Active Australia Survey [25] is a 9-item questionnaire to assess frequency and duration of physical activity levels. Total scores were computed from walking, vigorous and moderate physical activities: 'Sedentary' for 0 physical activity sessions; 'Insufficiently active'

for <150 minutes of total active time or ≥ 150 but <5 total active sessions; ‘Sufficiently active’ for ≥ 150 minutes and ≥ 5 sessions [25]. A 10-item food intake questionnaire was created from the Australian Dietary Guidelines [26]. Five calculated health levels were provided on a total scoring of points (See Figure 3): very unhealthy (0), mostly unhealthy (1-3), somewhat healthy (4-6), mostly healthy (7-9), and very healthy (10). The Opiate Treatment Index (OTI) is a five-item questionnaire to assess frequency of smoking and number of cigarettes [27]. A score representing average daily use was calculated [27]. Five levels of use were created from these scores: abstinence (0.00), once a week or less (0.01-0.13), more than once a week (0.14-0.99), daily (1.00-1.99) and more than once a day (2.00+). The Alcohol Use Disorders Identification Test (AUDIT-C) is a 3-item tool to identify alcohol misuse [28], [29]. Total score indicated level of risk of harm based on scoring guidelines: abstinence, low, moderate and high [29].

6) *Feedback Sheet*: The feedback sheet provided a health level based on total scores for physical activity, dietary intake, alcohol and cigarette use. This included a health advisory statement and resources for government-supported information, guidelines or programs for each behavior. Recommendations to seek a specialist service was given if people had smoked at least once a day.

Scoring	0	0.5	0.75	1
Vegetables	<5 serves/day	N/A	N/A	5+ serves/day
Fruit	<2 serves/day	N/A	N/A	2+ serves/day
Dairy	<2 serves/day	N/A	N/A	2+ serves/day
Lean Protein/poultry	<1 serve/day, >3 serves/day	N/A	N/A	1 to 3 serves/day
Wholegrain cereals	Never	Sometimes	Mostly	Always
Dairy reduced fat	Don't eat dairy, Never	Sometimes	Mostly	Always
Sugary drinks	Always	Mostly	Sometimes	Never
Takeaway	>Once/week	N/A	N/A	$\leq$ Once/week
Sweets	>Once/week	N/A	N/A	$\leq$ Once/week
Salty foods	>Once/week	N/A	N/A	$\leq$ Once/week

Fig. 3: Scoring System for Intake Level for the 10 Food Groups

III. RESULTS

1) *Experimental Data*: A total of 50 participants consented to the trial, but 3 were not clinic patients, leaving 47 to finish the session. Many requested a feedback sheet copy ($n = 30$, 64%) but 2 (7%) reported that it did not print. Further investigation showed that both print-related errors occurred in the same testing week. Only 2 (9%) gave the feedback sheet to a clinician. The session took 15.43 minutes on average to complete, below the waiting room time average of 20 to 40 minutes to avoid disrupting their clinical appointment [5]. In the 32 who agreed to a follow up, 23 completed it (72%). The rest were sent up to 5 reminders.

2) *Demographics*: There were more females ($n = 33$, 70%) than males ($n = 12$, 26%) or those who identified as other ($n = 2$, 4%). The mean age was 55 years old ($SD = 22.94$, Range = 18-84). Most were married ($n = 22$, 47%), single ($n = 12$, 26%) or in a relationship ($n = 7$, 15%). Others were widowed, separated, de-facto or divorced ($n = 6$, 12%). Patients reported working in medical or healthcare ($n = 9$, 19%), administration ($n = 7$, 15%), education and training ($n = 5$, 11%), different career fields ($n = 14$, 29%) or ‘other’ ($n = 12$, 26%). Many completed postgraduate education ($n = 9$, 19%), undergraduate ($n = 12$, 26%), Grade 12 ($n = 15$, 32%), Grade 10 ($n = 5$, 11%) or trades ($n = 6$, 13%). Most were not higher education students ($n = 37$, 79%). Patients had a moderate level of technological experience ($M = 5.66$, $SD = 2.72$), but very low levels of robotics ($M = 1.17$, $SD = 1.69$) and programming experience ($M = 1.36$, $SD = 1.92$).

3) *Robot Evaluation*: Patients reported high perceived ease of use ($M = 8.13$, $SD = 2.05$) and moderate usefulness ($M = 4.70$, $SD = 3.65$), and perceived motivation to make changes after the robot and practitioner interaction ($M = 4.57$, $SD = 3.09$) for physical activity ($M = 5.21$, $SD = 2.42$, $n = 19$), diet ($M = 5.1$, $SD = 2.75$, $n = 20$), less so for alcohol ($M = 2$, $SD = 2.62$, $n = 8$), but higher for cigarette use ($M = 7.5$, $SD = 2.12$, $n = 2$) from those who did not select ‘not applicable’. There was a mix of scores across robot preference, no difference and human preference for perceived comfort to discuss health-related topics (See Figure 4 and 5). There were no differences in comfort to talk to a robot or human about health-related topics, except for having a casual conversation, $F(46) = 9.845$, $p = .003$, $\eta^2 = .176$ (See Figure 4). Robot ‘Emotion’ scores were moderate ($M = 34.63/50$, $SD = 12.78$), including for ‘Social’ ($M = 19.18/30$, $SD = 7.57$), ‘Utility’ ($M = 20.64/40$, $SD = 11.74$) ‘Operation’ ($M = 42.86/60$, $SD = 17.24$) and ‘Application’ ($M = 29.27/50$, $SD = 13.43$) subscales. No correlations were found between robot emotion, social, utility, operation or application scores, and comfort to talk about health-related topics with the robot.

Topic	Robot	Human
Conversation	$M = 7.28$, $SD = 3.00$	$M = 8.51$, $SD = 1.72$
Physical Activity	$M = 8.13$, $SD = 2.12$	$M = 8.26$, $SD = 1.95$
Dietary Intake	$M = 8.19$, $SD = 2.12$	$M = 8.06$, $SD = 2.28$
Alcohol Use	$M = 8.45$, $SD = 2.30$	$M = 7.83$, $SD = 2.85$
Cigarette Use	$M = 8.09$, $SD = 3.04$	$M = 8.06$, $SD = 3.04$
Mental Health	$M = 6.96$, $SD = 3.26$	$M = 7.60$, $SD = 2.55$

Fig. 4: Patient Level of Comfort to Discuss Health-Related Topics to a Robot or Human

4) *Qualitative Responses*: Social robot evaluations were brief ($M = 9$ words): easy, interesting, good, straight forward, quite fun, easy to do, novel experience, not much trouble, not easy to read, strange, difficult wording of the question, trouble understanding robot speech, slow, not very helpful, a little awkward, lacked fluent interaction, a bit weird, creepy, comment about its sudden movement and more like using a tablet than a robot interaction. Responses on provision of the feedback sheet to their clinician were also brief ($M = 7$ words): forgetting, not seeing results as correct, visit involved

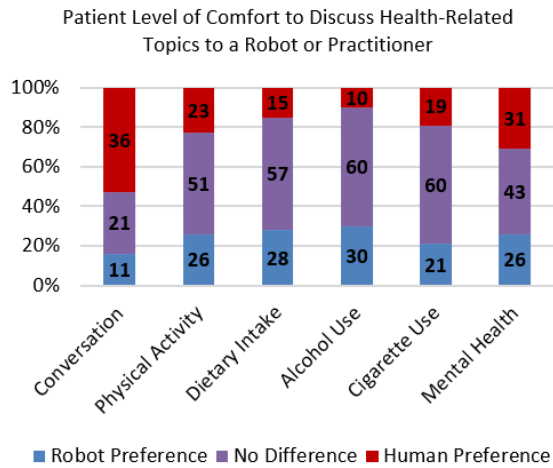


Fig. 5: Patient Level of Comfort to Discuss Health-Related Topics with a Robot or Person

other issues, not seeing their clinician or viewing the sheet as necessary for them to see.

5) *Health Factors*: Physical activity levels met scores for ‘Sufficiently active’: total walk time ($M = 186.87$ minutes, $SD = 140.78$), vigorous exercise time ($M = 170.66$, $SD = 375.20$) and moderate exercise time ($M = 141.83$, $SD = 245.28$). This included for total number of sessions ($M = 14.36$, $SD = 22.29$) and time ($M = 670.02$, $SD = 1010.46$). Final scoring showed that most patients had sufficient activity levels (Sufficiently Active = 37, 79%, Insufficiently Active = 10, 21%). Diet scores were sufficient ($M = 7.82/10$, $SD = 1.01$; Mostly healthy, $n = 38$, 81%; Somewhat healthy, $n = 9$, 19%). Alcohol risk score was low on average ($M = 2.70/12$, $SD = 2.52$; Low, $n = 32$, 68%; Moderate $n = 8$, 17%; High, $n = 5$, 11%, Severe, $n = 2$, 4%). Those who used cigarettes had on average at least one per day ($n = 5$, $M = 1.49$, $SD = 1.45$). No significant differences were found 30 days later for physical activity total minutes or number of sessions, diet, alcohol, or cigarette use.

IV. DISCUSSION

This study presents a novel approach to health assessment and education in the use of a social robot in a health clinic to promote health-related outcomes on key health factors: diet, physical activity, alcohol and cigarette use. The robot-delivered program aimed to explore how a social robot can conduct a rapid, robust, and automatic health assessment paired with feedback for low-intensity health promotion and education [3], [4]. No significant health changes were found across the 4-week period as most had adequate health levels, which left minimal opportunity for improvement over the follow-up period. Patients reported no differences in perceived comfort to discuss health-related topics with a robot or human including physical activity, diet, alcohol, cigarette use or mental health. Patients also found the robot easy to use in a healthcare context with moderate levels of reported usefulness and motivation to improve behavior

after the robot and health practitioner interaction. Qualitative responses identified some design adjustments, such as the functionality of the interaction and presentation of health information. There were few reported errors that occurred during deployment, as well as difficulties with deployment when working with clinic staff.

The trial found that older people were often in attendance and interested to participate in a health session delivered by the social robot. Social robots that provide health education for an older population should therefore be tailored to promote ease of access, clear understanding, and age-related assessment. This includes promotion of healthy lifestyle actions that older people can perform in this age range, such as independent living and improvement of physical function [30]. Other design considerations involve user experience elements that can accommodate a target population that is more likely to have hearing or visual impairment, such as adjustable font size and voice loudness. The target age group could also include education or screening questions for other conditions, such as a mammogram or skin check. This subgroup highlights the importance of co-design for older people to ensure they are not disadvantaged from the experience and their medical conditions are taken into consideration in recommended feedback sheets.

Program evaluation scores provided further insight about the prospective use of a social robot in a health clinic setting [3], [4]. Patients that had no strong preference for robots or humans for discussing health issues is a key finding. Some participants provided feedback on the utility of the robot interaction, suggesting both improved functionality and rationale for the interaction may be needed. The study provided ideas for other adjustments to the intervention. A large portion did not give the feedback sheet to their clinician, who may have not felt a need to discuss their scores, particularly if they had received positive feedback. Other patients may have felt there was insufficient time in the appointment or that the feedback responses were not reflective of their behavior or health status. This could include a clearer rationale to the patient on why sharing the feedback with their practitioner could be useful. Even if patients choose not to share their outcomes, this method still provides some benefit as a low-cost health promotion and maintenance service, offering up-to-date information on guidelines paired with praise for good adherence. Robots could therefore be a feasible method to promote awareness and health education in a health clinic for these topics, but may not require full integration into the clinician treatment process.

No significant health changes were found across the 4-week period because most individuals were meeting healthy levels from the first session. There was likely minimal motivation to further change a behavior that is already met on a daily basis. Instead, those not meeting current recommendations may require a more comprehensive approach above simple general recommendations, such as a longer robot-delivered program that builds motivation for behavior change with step-wise planning. A longer robot intervention may

better replicate similar studies that found positive changes or outcomes [9], [10], [14], [12].

A limitation of the robot interaction was the scoped nature of the questionnaire set, which did not allow for extensive health data collection or explanation of question sets. This allowed a clear focus on key factors and to meet the time allocation for each session. A limitation of the data collection phase was the low participation rates from practitioners, so material about their perception and interpretation of a social robot in a health clinic could not be explored in detail. Another involved the lack of comparison condition, which instead focused on initial autonomous deployment and testing of the robot-delivered intervention for health clinic integration, long-term functionality, and evaluation on its use as a stand-alone service. This feasibility trial provides an initial data and testing protocol to inform a more detailed randomized trial design, which is a common initial step in the research pathway [31], similar to other work conducted for the topic [15]. Initial investigations for implementation, likelihood of disruption to health clinic appointments, and scoping the willingness to conduct the session by individuals attending the clinic was met.

V. CONCLUSION

This study investigated the use of a social robot in a health clinic to provide a brief health assessment and feedback. This study demonstrated the success of a live autonomous deployment in a clinic without the need for monitoring, representing a more realistic value proposition to health clinics. This creates new opportunities for health promotion and treatment options on behaviors that require daily maintenance. Health practitioners can have limited time to discuss health behaviors with patients, and this novel approach gave patients an opportunity to start the conversation before their appointment. This includes saving practitioner time during the session and identifying issues they might not otherwise have had the opportunity to draw out [32]. This serves to assist clinicians in promotion of daily health behaviors when appointments are needed for other issues. Provision of a feedback sheet and recommended programs offer a clear first step as a low-intensity program for health promotion, and to bring awareness to the impact of daily health-related behavior. Future iterations could involve additional personalization, technical refinement of the robot interaction, behavioural data collected from the patient, co-design of session content with practitioners in other health clinics, and strengthening segments on building motivation and planning for further improvements to health behaviors.

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REFERENCES

- [1] N. C. Clarke, M. Field, and A. K. Rose, "Evaluation of a brief personalised intervention for alcohol consumption in college students," *PLoS one*, vol. 10, no. 6, pp. e0131229–e0131229, 2015.
- [2] World Health Organization, "Global status report on noncommunicable diseases," 2014.
- [3] R. Boumans, F. van Meulen, K. Hindriks, M. Neerinx, and M. G. M. Olde Rikkert, "Robot for health data acquisition among older adults: a pilot randomised controlled cross-over trial," *BMJ Quality and Safety*, 2019.
- [4] P. Briggs, M. Scheutz, and L. Tickle-Degnen, "Are robots ready for administering health status surveys": first results from an hri study with subjects with parkinson's disease," in *ACM/IEEE International Conference on Human-Robot Interaction*, 2015, Conference Proceedings, pp. 327–334.
- [5] D. McIntyre and C. K. Chow, "Waiting time as an indicator for health services under strain: a narrative review," *Inquiry: A Journal of Medical Care Organization, Provision and Financing*, vol. 57, pp. 46958020910305–46958020910305, 2020.
- [6] K. J. Vänni and S. E. Salin, "A need for service robots among health care professionals in hospitals and housing services," in *International Conference on Social Robotics*. Springer, 2017, Conference Proceedings, pp. 178–187.
- [7] H. S. Ahn, S. Zhang, M. H. Lee, J. Y. Lim, and B. A. MacDonald, "Robotic healthcare service system to serve multiple patients with multiple robots," in *International Conference on Social Robotics*. Springer, 2018, Conference Proceedings, pp. 493–502.
- [8] N. L. Robinson, T. V. Cottier, and D. J. Kavanagh, "Psychosocial health interventions by social robots: systematic review of randomized controlled trials," *Journal of Medical Internet Research*, vol. 21, no. 5, p. e13203, 2019.
- [9] N. L. Robinson, J. Connolly, L. Hides, and D. J. Kavanagh, "A social robot to deliver an 8-week intervention for diabetes management: Initial test of feasibility in a hospital clinic," in *Social Robotics*, A. R. Wagner, D. Feil-Seifer, K. S. Haring, S. Rossi, T. Williams, H. He, and S. Sam Ge, Eds. Springer International Publishing, 2020, Conference Proceedings, pp. 628–639.
- [10] J. Galvão Gomes da Silva, D. J. Kavanagh, T. Belpaeme, L. Taylor, K. Beeson, and J. Andrade, "Experiences of a motivational interview delivered by a robot: Qualitative study," *Journal of Medical Internet Research*, vol. 20, no. 5, p. e116, 2018.
- [11] F. Martí Carrillo, J. Butchart, S. Knight, A. Scheinberg, L. Wise, L. Sterling, and C. McCarthy, "Adapting a general-purpose social robot for paediatric rehabilitation through in situ design," *ACM Transactions on Human-Robot Interaction (THRI)*, vol. 7, no. 1, pp. 1–30, 2018.
- [12] J. Fasola and M. J. Matarić, "A socially assistive robot exercise coach for the elderly," *Journal of Human-Robot Interaction*, vol. 2, no. 2, p. 3–32, Jun. 2013.
- [13] A. Guneyasu and B. Arnrich, "Socially assistive child-robot interaction in physical exercise coaching," in *26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, 2017, Conference Proceedings, pp. 670–675.
- [14] N. L. Robinson, J. Connolly, L. Hides, and D. J. Kavanagh, "Social robots as treatment agents: Pilot randomized controlled trial to deliver a behavior change intervention," *Internet Interventions*, vol. 21, p. 100320, 2020.
- [15] I. Papadopoulos, C. Koulouglioti, R. Lazzarino, and S. Ali, "Enablers and barriers to the implementation of socially assistive humanoid robots in health and social care: A systematic review," *BMJ open*, vol. 10, no. 1, p. e033096, 2020.
- [16] World Health Organization, "Noncommunicable diseases," 2018.
- [17] M. H. Forouzanfar, A. Afshin, L. T. Alexander, H. R. Anderson, Z. A. Bhutta *et al.*, "Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2013: A systematic analysis for the global burden of disease study 2015," *The Lancet*, vol. 388, no. 10053, pp. 1659–1724, 2016.
- [18] J. Manthey, K. D. Shield, M. Rylett, O. S. Hasan, C. Probst, and J. Rehm, "Global alcohol exposure between 1990 and 2017 and forecasts until 2030: A modelling study," *The Lancet*, vol. 393, no. 10190, pp. 2493–2502, 2019.
- [19] M. B. Reitsma, N. Fullman, M. Ng, J. S. Salama, A. Abajobir, K. H. Abate, C. Abbafati, S. F. Abera, B. Abraham, G. Y. Abyu *et al.*, "Smoking prevalence and attributable disease burden in 195 countries and territories, 1990–2015: a systematic analysis from the global

- burden of disease study 2015," *The Lancet*, vol. 389, no. 10082, pp. 1885–1906, 2017.
- [20] S. S. Lim, T. Vos, A. D. Flaxman, G. Danaei, K. Shibuya, H. Adair-Rohani *et al.*, "A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: A systematic analysis for the global burden of disease study 2010," *The Lancet*, vol. 380, no. 9859, pp. 2224–2260, 2012.
 - [21] M. Reiner, C. Niermann, D. Jekauc, and A. Woll, "Long-term health benefits of physical activity—a systematic review of longitudinal studies," *BMC Public Health*, vol. 13, no. 1, pp. 813–813, 2013.
 - [22] 2020. [Online]. Available: <https://developer.softbankrobotics.com/pepper-naoqi-25/pepper-documentation/pepper-developer-guide>
 - [23] G. Suddrey and N. Robinson, "A software system for human-robot interaction to collect research data: a html/javascript service on the pepper robot," in *HRI'20 Companion: Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction*. Association for Computing Machinery (ACM), 2020, Conference Proceedings, pp. 459–461.
 - [24] N. L. Robinson, J. Connolly, G. M. Johnson, Y. Kim, L. Hides, and D. J. Kavanagh, "Measures of incentives and confidence in using a social robot," *Science Robotics*, vol. 3, no. 21, p. eaat6963, 2018.
 - [25] Australian Institute of Health and Welfare, *The Active Australia survey: A guide and manual for implementation, analysis and reporting*. Canberra: Australian Institute of Health and Welfare, 2003.
 - [26] Australian Government Department of Health, "Australian dietary guidelines," 2013.
 - [27] S. Darke, J. Ward, W. Hall, N. Heather, and A. Wodak, "The opiate treatment index (oti) researchers' manual," 1991.
 - [28] K. A. Bradley, A. F. Debenedetti, R. J. Volk, E. C. Williams, D. Frank, and D. R. Kivlahan, "Audit-c as a brief screen for alcohol misuse in primary care," *Alcoholism: Clinical and Experimental Research*, vol. 31, no. 7, pp. 1208–1217, 2007.
 - [29] W. H. Organization *et al.*, "Audit: The alcohol use disorders identification test: Guidelines for use in primary health care," World Health Organization, Tech. Rep., 2001.
 - [30] J. Sims, K. Hill, S. Hunt, and B. Haralambous, "Physical activity recommendations for older australians," *Australasian Journal on Ageing*, vol. 29, no. 2, pp. 81–87, 2010.
 - [31] B. Morgan, J. Hejdenberg, S. Hinrichs-Krapels, and D. Armstrong, "Do feasibility studies contribute to, or avoid, waste in research?" *PloS one*, vol. 13, no. 4, p. e0195951, 2018.
 - [32] M. Deveugele, A. Derese, A. van den Brink-Muinen, J. Bensing, and J. De Maeseneer, "Consultation length in general practice: cross sectional study in six european countries," *BMJ*, vol. 325, no. 7362, p. 472, 2002.