# A Robotic Companion for Psychological Well-being: A Long-term Investigation of Companionship and Therapeutic Alliance

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## Abstract

Social support plays a crucial role in managing and enhancing one's mental health and well-being. In order to explore the role of a robot's companion-like behavior on its therapeutic interventions, we conducted an eight-week-long deployment study with seventy participants to compare the impact of (1) a *control robot* with only assistant-like skills, (2) a *coach-like robot* with additional instructive positive psychology interventions, and (3) a *companion-like robot* that delivered the same interventions in a peer-like and supportive manner. The companion-like robot was shown to be the most effective in building a positive therapeutic alliance with people, enhancing participants' well-being and readiness for change. Our work offers valuable insights into how companion AI agents could further enhance the efficacy of the mental health interventions by strengthening their therapeutic alliance with people for long-term mental health support.

### Keywords

Social Robot; Positive Psychology; Psychological Well-being

## 1 INTRODUCTION

Mental health and well-being impact the way people think, feel, and act, as well as their health management behaviors and decisions [49]. Social robots have found a unique opportunity to demonstrate their value to promote people's well-being by creating new

avenues to access services and resources for mental health in real world contexts [6, 8, 30]. However, most existing interactive agents for mental health present themselves as an expert coach that "teaches" or "guides" people by providing psycho-education and behavioral reinforcement. These technologies monitor the user's health behavior and progress, and offer instructions, rather than sharing the long-term behavioral change journey.

Interactive agents have opportunities to further enhance the efficacy of mental health interventions by both providing psycho-educational contents and acting as a companion that provides shared experience through self-disclosures. Research on clinicians' self-disclosures found evidence that a care-provider's self-disclosure could result in more positive perception of the treatment when done in an appropriate context [46, 70]. In the context of human-robot interactions, a robot's self-disclose and leaning-forward behaviors have been shown to increase people's engagement and attention [31], and a robot's disclosure of high vulnerability elicited more vulnerable disclosures from high school students [42].

Based on these existing works, we propose a social robot to deliver mental health interventions in a "*companion-like*" style, in which the agent uses self-disclosure and peer-like social support behaviors in delivering the intervention. We extend the study done by Jeong et al. [29, 30] by adding this *companion-like* robot style, in which the robot does not instruct the human user but demonstrates the intervention activity first and invites the user to join in, instead of using explicit directives for instructions as in the original study. The robot also acts like a peer who also participates in the positive psychology activities for shared experience and uses self-disclosures to strengthen the human-robot rapport. We designed a study to evaluate that a robot that demonstrates positive psychology intervention activities and uses self-disclosures behaviors deepens the rapport with its user and further enhances the efficacy of the mental health interventions it offers (Figure 1).

## 2 RELATED WORKS

### 2.1 Positive Psychology Interventions

Positive psychology is defined as the "scientific study of what makes life most worth living," which aims to improve people's personal strengths and positive aspects of their lives in order to enhance their flourishing [52, 57]. According to Parks and Biswas-Diener [51], positive psychology interventions (PPIs) focus on positive themes that result in positive outcomes by enhancing individual strengths, happiness, and flourishing, unlike interventions in traditional clinical psychology that mainly aim to address weaknesses and treat mental pathology.

PPIs have been used in various contexts for a wide range of populations, e.g., adolescents in school [60], patients with chronic pain management [10], and older adults in community centers [25]. A meta-analysis done by Boiler et al. [9] found that randomized clinical studies of PPIs could improve subjective and psychological well-being while reducing depressive symptoms for both the general public and patients with mental health conditions. Topics in PPIs include gratitude [17], optimism [7], character strengths [50], resilience [41], savoring [11], and self-compassion [47]. We present further details on the PPIs used in the study in Section 3.4.

### 2.2 Social Support

Feeling supported, loved, and valued by others, i.e., social support, have been shown to positively influence both psychological and physiological health [20, 26, 27, 33]. The stress buffering model suggests that social support diminishes the negative health effects of stress [14]. Hyde et al. [28] found that social support could modify neural reactivity to threat-related anxiety. They found that people with low social support showed a positive correlation between amygdala reactivity and several measures of trait anxiety, while people with high perceived social support did not.

Social support can be categorized into four different types [69]: emotional support, instrumental support, informational support, and companion support. *Instrumental support* refers to the provision of tangible and direct support, such as financial/material assistance, goods, or services [21]. *Informational support* refers to offering information, advice, or guidance that could help others solve problems [36, 66]. *Emotional support* refers to empathy, concern, encouragement and intimacy provided by others in order to let people know that they are valued [36, 61]. Lastly, *companionship support* refers to giving someone a sense of social belonging and a sense of going through an experience together [67, 69]. In our work, we designed our *companion-like* robot to provide additional emotional and companionship support via self-disclosing and empathetic behaviors.

### 2.3 Self-disclosures

Disclosing one's feelings, thoughts, and experiences can provide insightful information and is essential in building and developing relationships [23, 64]. Self-disclosures are highly reciprocal in human-human interactions [15], and computer agents' self-disclosure has also been shown to be reciprocated by humans. Moon [44] found that people are more likely to disclose intimate information about themselves and were also more attracted to the agent if a computer agent self-disclosed about itself. A study done by Lee et al. [37] found that a chatbot agent that self-discloses during small talk promoted deeper self-disclosures, perceived intimacy and enjoyment from its users than a chatbot without the self-disclosure feature. Reciprocal disclosure of information, affect, and activities improves coordination and increases liking among people in the exchange [13, 62], and develops interpersonal relationship and bonding [12].

### 2.4 Therapeutic Alliance and Health Outcomes

Positive working alliance between the agent and its user could amplify the effect of the intervention the agent offers. The rapport between clinicians and patients is a predictor of improved health outcomes and patients' adherence to their prescribed regimens and satisfaction with their treatments [19, 54, 68]. Strong rapport also helps patients to cope with stress [54], enabling stronger clinician-patient collaboration and agreement on treatment, which leads to the long-term behavioral changes required for successful health outcomes [54].

Rapport can also increase people's willingness to self-disclose, which is a critical part of mental health interventions. Computer-based agents are often designed and perceived as non-judgmental interaction partners [5]. Hence, this perceived anonymity enables people

to be more willing to disclose sensitive or stigmatized information about themselves to an embodied conversational agent than to another human conversational partner [22, 40]. Based on these findings, we explored how enhancing the human-robot rapport could positively contribute to the effectiveness of the technology-mediated mental health support.

### 2.5 Robotic Companions

Companion-like behaviors of a social robot have been explored in previous works. Stiehl et al. [63] developed a robotic platform that is designed to surrogate pet therapy through affective touch interactions, and Fogelson et al. [18] studied the effect of a pet-like robot in reducing depression and loneliness for older adults during the COVID-19 pandemic. A humanoid robot developed by Abdollahi et al. [1] engaged in conversations and offered reminders for schedules, cognitive games, and reminiscence activities for older adults in home context. Studies done by Leite et al. [38, 39] explored the impact of four social support types on human-child play interaction through a long-term study. Jeong et al. [29, 30] deployed a robotic coach that delivered seven daily positive psychology sessions to college students living in on-campus dormitories.

Our work extends the study done by Jeong et al. [29, 30] by exploring the impact of a robot's companion-like behavior in improving engagement and perceived social support. A *companion-like* robot style was designed and compared to Jeong et al.'s original *coach-like* condition. In addition, we have added a baseline *control* condition, in which the robot provided assistant-like support but did not deliver any positive psychology intervention. Our participant pool was expanded to include general adult population and to evaluate the effect of the robotic intervention over longer duration (four weeks). With these additional experimental conditions, we investigate how empathetic and self-disclosure behaviors expressed by the robot could enhance the therapeutic alliance in delivering evidence-based mental health interventions.

## 3   EXPERIMENTAL STUDY

### 3.1   Participants

We recruited 80 participants who (1) lived in the U.S., (2) had wireless Internet access with WPA-PSK/WPS2-PSK authentication, (3) were able to setup wifi connection or had someone who could help, (4) did not have any visual/auditory/oral disabilities, and (5) were not receiving treatment for depression. The study protocol was reviewed and approved by the Institution Review Board, and all participants signed the consent form prior to the study that detailed the study procedure and data collection plans. A randomized block design based on age, gender and personality traits were used to balance participants across the three study conditions. Out of eighty people recruited, seventy participants completed the study (age $M$=48.225, $SD$=23.374, $min$=18, $max$=83; 46 Female, 20 Male, and 4 Other). Ten participants withdrew from the study due to sudden health issues (1), robot hardware damage (1), technical difficulties (3), concern for security regarding work (1), work-related travel (2), lost interest (1), and unknown reason (1). We have included detailed descriptive statistics of participants' age, ethnicity, gender, and Big Five personality traits across the three conditions in the Appendix.

### 3.2 Experimental Conditions

Participants were randomized into one of the three study conditions: (1) *control* condition, (2) *coach-like* condition, and (3) *companion-like* condition. Participants in the two experimental groups (the *coach-like* condition and the *companion-like* condition) received a robot station that is equipped with twelve positive psychology interventions that are each 5–7 minutes-long.

The *control* robot had its basic consumer skills, such as weather forecast, general Q&A, music streaming, proactive pleasantries, chit-chat, games, etc., but did not provide any positive psychology intervention. The *coach-like* robot acted as an instructor who has expertise in the positive psychology interventions. It offered direct instructions on each intervention step, and instructed participants to complete the intervention content during the session and sometimes as a homework assignment. It used a friendly tone and face/body animations that aligned with the behaviors in the rest of the robot skills. Often, it used generic examples to help participants come up with ideas and plans for the activity. On the other hand, the *companion-like* robot presented itself as a peer who also is learning the positive psychology interventions with the participant. It introduced the intervention contents after "learning from another friend" or "looking up on the Internet," and gently asked whether the participant would like to try the activity together. Since both participants and the robot engaged in the intervention activity, the robot shared its own thoughts and experiences (self-disclosures) according to the intervention prompt, and encouraged participants to also share their thoughts. A video with an example of *coach-like* and *companion-like* robot behavior is submitted as a supplemental material.

### 3.3 Method

Online advertisement was distributed by the research team through the institution's social media account, personal contacts, and older adult retirement community mailing lists. A consent to participate in the study was obtained electronically via DocuSign[1], and we administered a set of questionnaires including demographic information, Mini-IPIP, and PHQ-9. Once the study started, participants received weekly survey assessments via email. These measures are detailed in Section 4.1.

The robot station that integrated a robot, an Android tablet, and a Raspberry Pi was shipped to arrive after the first two-week baseline period (Figure 2a). Along with the robot station, we sent a small notepad, alcohol wipes, a reusable cleaning cloth, an instructional booklet to guide the installation and proper usage of the robot system to participants (Figure 2b). In case of any technical difficulties and troubleshooting, a research assistant (RA) scheduled a video conference meeting or a phone call with participants to address any technical issues.

An A-B-A design was used to evaluate participants' well-being, affect, and motivation for better psychological well-being in three phases – before the study, during robot intervention, and after the removal of the robot. Participants were monitored for eight weeks in total. The first and last two weeks of the study were conducted without the robot, for baseline and pre-

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[1] https://www.docusign.com/

and post-intervention assessments. Participants were asked to host the robot in their home for the four weeks in between, and to complete weekly assessments for their psychological well-being, affect, and motivation for health behavior change throughout the eight-week period.

During the four-week robot interaction phase, participants were asked to interact with the robot at least three times a week for 5–10 minutes (12 total required sessions). The positive psychology based "wellness" sessions were video/audio recorded through the Android tablet and the USB camera on the robot station. The system did not record any footage outside of these intervention sessions. Participants were also asked to freely interact with the robot outside the designated wellness sessions as they'd like. Participants' robot usage data was collected by storing the robot's system logs.

Forty robot stations were available for this project, and thus the study was conducted in two deployment phases. The first round deployment occurred in February-March 2021, and the second round occurred in August-September 2021.

### 3.4   Robot-mediated Positive Psychology Interventions

A series of evidence-based positive psychology interventions were adapted to be delivered by our robot. Twelve interaction sessions were designed based on positive psychology interventions [11, 53, 55, 58, 59] with four weekly themes: gratitude, meaningful connection, self-compassion, and character strengths. The intervention contents in the *coach-like* and the *companion-like* conditions are presented in the Appendix, to support replicability of this work.

When powered on for the first time in the participants' homes, the robot will offer an Out-Of-the-Box Experience. The purpose of this interaction was to offer the user and the robot to learn each other, the first step toward establishing rapport. The robot introduces itself and then learns the user's face and voice. It also walks through its interaction features and functions, e.g. how to get the robot's attention, how to use the touch screen to navigate the GUI menus, how to launch the positive psychology skill ("Hey [robot name], can we talk about wellness?"), etc. During the study period, the robot will also proactively ask the user to engage in the positive psychology session if the user has not completed the session within the day (e.g. "Hey, do you have time to talk about positive psychology?").

During the first positive psychology interaction (**session 1**), the robot made a brief introduction to positive psychology and explained the study procedure. In **session 2**, the robot introduced what gratitude was and its importance. Participants were guided to complete the "three good things in life" exercise [59], in which they wrote down and reflected on three things that went well that day and why they went well. In **session 3**, participants were introduced to the "gratitude by eliminination" exercise [34]. In this activity, participants were asked to select one thing that was very positive and important to them, and imagined how their lives would be like if it did not exist. The second week included three sessions on making meaningful connections with other people. In **session 4**, participants were asked to think of someone who they felt grateful for, and verbally express why they were grateful for that person. In **session 5 and 6**, the robot introduced

participants about mindful listening [4], which is a way of listening without judgment, criticism or interruption while giving them full attention. Participants were first asked to reflect their typical conversation behaviors by observing whether they and their interlocutor are mindful listeners or not (**session 5**). In the next session (**session 6**), they learned how to practice mindful listening by making eye contacts and being present with the person they converse with. Self-compassion was introduced in the third week. In **session 7**, participants learned to appreciate themselves by thinking of three good things they did or achieved that day, in a similar manner to the "three good things" exercise. In **session 8**, participants were introduced to the savoring exercise [11] that could help them slow down and enjoy experiences that people normally hurry through. In **session 9**, the robot guided participants through the "treating yourself as your friend" activity. This exercise asked participants to think about times when a close friend feels really bad about him or herself, and prompts them to compare how they respond to the friend's struggle to when they respond to themselves in the same situation. Participants were asked to identify factors that cause them to treat themselves and their friends differently, and come up with a plan to treat themselves with more compassion. **session 10**, the robot introduced character strengths, which are positive, trait-like capacities for thinking, feeling and behaving in ways that benefit oneself and others [48]. The tablet app listed descriptions of 24 character strengths and participants were asked to select five strengths that best reflect who they are as their *signature strengths* [53]. The robot then invited participants to share how they use their signature strengths in daily lives. **session 11**, participants created a plan to "use [their] signature strengths in a new way" [43, 59]. They visualized completing this plan with the robot and were encouraged to carry out the plan before the next session as homework. In **session 12**, participants reviewed all the sessions and concluded the interaction.

## 3.5 Hypotheses

The following hypotheses were tested to evaluate the effectiveness of the robot intervention and how working alliance formed between the user and the robot impacts positive psychology outcomes.

**H1.** Participants in the *coach-like* condition and the *companion-like* condition will show improved psychological well-being, affect, and readiness to change after the study, while participants in the *control* condition will not show any significant change.

**H1a.** Also, the *companion-like* robot will result in higher improvement in well-being, affect, and readiness to change than the *coach-like* robot.

**H2.** Participants' working alliance with the robot will be positively correlated with their improvement in psychological well-being, overall affect, and readiness to change.

**H2a.** And participants in the *companion-like* condition will report the highest working alliance with the robot, followed by participants in the *coach-like* condition, and participants in the *control* condition.

# 4   DATA COLLECTION AND MEASURES

## 4.1   Self-report Measures

For pre-screening procedure, the Mini-IPIP [16] and the PHQ-9 [35] were administered to measure potential participants' personality traits and risk for depression. The Mini-IPIP (International Personality Item Pool) scale [16] is a 20-item short form of the 50-item of IPIP that measures Big Five personality traits, and consist of phrases describing a behaviour or a trait (conscientiousness, agreeableness, neuroticism, openness to experience and extroversion).

During the study, three self-report questionnaires were administered to measure study participants' psychological well-being (Ryf's Psychological Well-being Scale [32]), affect (Positive and Negative Affect Schedule Short Form [65]), and readiness to change (Readiness Ruler [24]) on a weekly basis. The Ryf's Psychological Well-being Scale (RPWS) [56] was used to measure participants' psychological well-being with six sub-scales (autonomy, environmental mastery, personal growth, positive relations with others, purpose in life and self-acceptance). The Positive and Negative Affect Schedule-Short Form (PANAS-SF) is a 20-item scale that is widely used to measure mood or emotion with ten items for measuring positive affect (e.g., excited, inspired) and ten items measuring negative affect (e.g., upset, afraid). The Readiness Ruler (RR) is commonly used to measure participants' willingness and motivation to make behavior changes for better well-being. We asked participants' perceived importance and confidence to make behavior change for better well-being. For the importance to change (RR_imp), we asked "how important it is for you to make behavior change for better well-being?" and the confidence to change (RR_conf) asked "how confident are you about making behavior change for better well-being?", all on a scale of zero to ten.

At the end of the study, participants completed the Working Alliance Inventory-Short Revised (WAI-SR) [45] to evaluate their perceived rapport with the robot. The WAI-SR assesses the extent of collaboration between a clinician/therapist and a client on three sub-scales (bond, goals and tasks).

## 4.2   Video and Audio Data

The positive psychology sessions with the robot were video/audio recorded via the Android tablet and the USB camera connected to the Raspberry Pi on the robot station. Whenever the system was recording, the Android application displayed a live video feed at the bottom right corner on the tablet screen to notify the recording status. Once the session with the robot was completed, the tablet application uploaded the recorded data with other relevant meta data to Amazon S3, and the local data was deleted from the tablet. After the study, the audio data was transcribed by a professional transcription vendor[2].

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[2] https://www.rev.com/

### 4.3  Post-study interview

We conducted a semi-structured interview with each participant at the end of the study to gain more qualitative feedback on the interaction. During the interview, participants shared their overall experience with the study, things they liked/disliked about the robot and the intervention sessions. We also asked whether they would continue practicing the positive psychology activities after the study, and whether there were any features they would like to see in robots in the future. The whole list of the interview questions are as below in the Appendix, to support replicability of this work. All interview responses were audio-recorded and transcribed for qualitative analysis.

## 5  RESULTS

We present the results from our analyses in this section. The acronyms refer to the following: *RPWS_total*, overall well-being; *RPWS_A*, autonomy; *RPWS_EM*, environmental mastery; *RPWS_PG*: personal growth; *RPWS_PR*, positive relations with others; *RPWS_PL*, purpose in life; *RPWS_SA*, self-acceptance. *PANAS_total* refers to overall affect; *PANAS_PA*, positive affect; *PANAS_NA*, negative affect; *RR_imp*, importance for well-being change; *RR_conf*, confidence for well-being change. The *PANAS_total* is calculated by *PANAS_PA-PANAS_NA*.

### 5.1  Impact of Robot Intervention on Well-being, Affect, and Readiness to Change

Linear mixed effect regression models showed that experimental conditions made significant impact on participants' well-being, affect, and readiness to change. For the *control* condition, negative affect showed statistically significant decrease over time (*PANAS_NA*, *coef*=−0.050, *p*=0.009). For the *coach-like* condition, overall well-being (*RPWS_total*, *coef*=0.023, *p*=0.048) and overall affect (*PANAS_total*, *coef*=0.074, *p*=0.004) showed significant improvement and negative affect (*PANAS_NA*, *coef*=−0.050, *p*=0.004) showed significant reduction. For the *companion-like* condition, overall well-being (*RPWS_total*, *coef*=0.033, *p*=0.030), personal growth (*RPWS_PG*, *coef*=0.038, *p*=0.036), self-acceptance (*RPWS_SA*, *coef*=0.047, *p*=0.014), and confidence for change (*RR_change*, *coef*=0.105, *p*=0.010) showed statistically significant improvement and negative affect (*PANAS_NA*, *coef*=−0.036, *p*=0.004) showed statistically significant decrease during the study. Overall, we found that both *coach-like* and *companion-like* conditions made positive impacts on intervention outcomes but the *companion-like* robot resulted in the biggest change in psychological well-being. Table 1 shows the results from the linear mixed regression models and Figure 3 show plots of statistically significant results.

### 5.2  Impact of Working Alliance on Intervention Outcomes

A Kruskal-Wallis test showed that there were significant differences among participants' working alliance with the robot across the three experimental conditions: *control MD*=1.958, *coach-like MD*=3.333, *companion-like MD*=3.750; $\chi^2(2)$=14.409, *p*<0.001. Post-hoc Dunn tests showed that the *control* condition was significantly lower than the *coach-like* (*p*=0.005) and the *companion-like* (*p*<0.001) condition.

Further analyses were conducted to investigate the differences in three elements (*Goal*, *Task*, and *Bond*) of the WAI-SR. Kruskal-Wallis tests on each element showed that all three elements were significantly different across the conditions: *WAI-SR Goal*, $\chi^2(2)$=15.191, $p$<0.001; *WAI-SR Task*, $\chi^2(2)$=17.966, $p$<0.001; *WAI-SR Bond*, $\chi^2(2)$=7.509, $p$=0.023. The medians for the *WAI-SR Goal* are: *control MD*=1.500, *coach-like MD*=3.250, *companion-like MD*=3.500. The medians for the *WAI-SR Task* are: *control MD*=2.000, *coach-like MD*=3.250, *companion-like MD*=3.375. The medians for the *WAI-SR Bond* are: *control MD*=2.375, *coach-like MD*=4.000, *companion-like MD*=4.500 (Figure 4).

Post-hoc Dunn tests were conducted for pairwise comparisons. For the *WAI-SR Goal*, the *control* condition was significantly lower than the *coach-like* ($p$=0.010) and the *companion-like* condition ($p$<0.001) conditions. For the *WAI-SR Task*, the *control* condition was lower than the *coach-like* condition ($p$<0.001) and the *companion-like* condition ($p$<0.001). For the *WAI-SR Bond*, the *control* condition was significantly lower than the *companion-like* condition ($p$=0.026) but was not significantly different from the *coach-like* condition ($p$=0.067).

Although there was no significant difference between the *coach-like* and *companion-like* conditions, a contrast coded generalized linear regression model showed a statistically significant trend of increase in the level of working alliance across the three experimental condition (*control* < *coach-like* < *companion-like*) for the overall working alliance and each WAI-SR element: *WAI-SR Total* $p$<0.0001; *WAI-SR Goal* $p$<0.0001; *WAI-SR Task*, $p$<0.0001; *WAI-SR Bond*, $p$=0.012.

Spearman's correlation coefficients between participants' working alliance and study outcomes were calculated to test for **H2**. The goal and task factors of participants' working alliance were positively correlated with their change in well-being ( *RPWS_total*). However, overall affect or readiness to change were not associated with participants' self-reported alliance with the robot (Table 2).

## 5.3 Post-study Interview

Overall, participants enjoyed engaging in the wellness activities with the robot (85%). Participants most enjoyed (1) the opportunities to reflect and introspect on their own experiences/well-being, (2) the robot's positivity and behavioral reinforcement on intervention materials, and (3) the overall positive psychology intervention contents. The study sparked curiosity for participants to learn more about well-being activities and motivated them to continue practicing them after the study. Several participants mentioned that they were willing to keep practicing and utilizing the intervention activities they learned from the study even after the robot was no longer with them. P20 noted that she shared one of the interventions she learned from the study with a friend who asked for help.

The robot's guidance with the wellness program was also appreciated. P06 said "I found that part [gratitude session] really profound because geez, I could list about 30 or 40 things that I'm grateful for. Um, and COVID has made life very difficult for all of us and, um, I just feel like my life has just literally been a miracle. It's, it, it went from 0 all the way around to 360. So, um, I very much enjoyed that." P23 and P46 noted it was easy to

understand the intervention materials and the assigned exercises were easily comprehended and implemented in their daily lives, and P20 appreciated the examples and anecdotes the robot shared.

However, some participants said it took some time to get accustomed to having the robot in their homes. P06 said, "I mean, I had to get used to him. (laughing). He's just a typical kid that, you know, somebody drop, your friend you haven't seen in 10 years and they drop of their son say-Can he stay with you for a week, something's come up? And so you have to get used to the kid, right?".

## 6    DISCUSSION

Our long-term home deployment study showed that the positive psychology intervention delivered by our robots made a positive impact on participants' well-being, affect, and readiness to change (**H1**), which align with the previous finding from Jeong et al. [29]. Overall, we found that the *companion-like* robot was the most effective (**H1a**). Participants who lived with the *companion-like* robot showed significant improvements in their psychological well-being (*RPWS_total*), personal growth (*RPWS_PG*), self-acceptance (*RPWS_SA*), and confidence for well-being change (*RR_conf*). With the *coach-like* robot, participants showed improved overall psychological well-being (*RPWS_total*) and overall affect (*PANAS_total*).

Interestingly, participants in the experimental condition reported higher therapeutic alliance with the robot compared to participants in the *control* condition in all three categories (goal, task, and bond), and a consistent trend of the *companion-like* robot being rated higher than the *coach-like* robot was observed (**H2a**). Correlation analyses between the intervention outcomes and working alliance found that participants' rapport with the robot was positively associated with improvement in psychological well-being (**H2**). This result suggests that the human-robot rapport could either impact or indicate the effectiveness of the well-being interventions delivered through the robot, just as clinician-patient rapport is repeatedly shown to be a predictor for treatment outcomes in prior literature.

Jeong et al. [29, 30] showed that positive psychology interventions delivered by a *coach-like* robot are associated with college students' improved well-being outcomes. Results from our study suggest that the human-robot alliance and rapport could amplify the positive therapeutic impact on people's well-being outcomes and their motivation for behavior change. In addition, an exploratory analysis on non-verbal cues observed during human-robot interactions found that relaxed vocal expression, positive facial expression, and physical engagement behaviors were associated with the intervention outcomes [30]. Results from these two studies suggest that there is an opportunity for an interactive agent to observe users' behavior and infer how well the interaction is going, in order to continuously personalize and adapt its relationship with the user to enhance the intervention effect.

Evaluating the effect of a long-term robot intervention in the real world is challenging since it is impossible to isolate the effect of other external factors. For example, participants in all three conditions showed a significant trend of negative affect decreasing over time.

This shows that the effect must have come outside the positive psychology intervention the experimental condition robots (*coach-like* and *companion-like*) provided. The co-presence of the robot could have contributed to the reduction of negative affect, but other factors such as the weather (winter to spring, spring to summer) could have attributed to the trend. While it is impossible to control all the external variables, we attempted to balance out their effect by fairly but randomly distributing participants across conditions based on their age, gender, and personality traits. Even so, we acknowledge that our results could have been influenced by factors other than the positive psychology interventions provided by the robot.

One limitation in our work is that only self-reported measures and interview data were used to evaluate the effect of our robot intervention. Although the self-reported questionnaires used in the study were previously validated and are widely used in clinical settings, they may contain response bias and inaccurate reflection of participants' internal state [2]. Future studies that use a multi-method assessment approach that combines both self-reported responses and objective physiological measures would allow improved evaluation of the intervention and provide a more accurate and holistic understanding of its impact.

Our future work will focus on investigating how people's linguistic, verbal, and non-verbal behaviors change over time as they develop relationship and rapport with the agent, and what behavioral signs indicate and inform the growth or decay of the human-agent alliance through long-term interactions and data collection. Social penetration theory [3] proposes that the breadth and depth of self-disclosures moves from shallow/non-intimate topics to deeper/more-intimate ones as interpersonal relationship develops. We believe some of negative feedback on the robot's behavior could have stemmed from the mismatch between the participant's perceived relationship with the robot and the robot's prosocial and self-disclosure behavior, which was viewed as a violation of social norm. In order to mitigate such mismatch between the robot's behavior and a user's perceived relationship with the robot, the robot should continuously monitor and manage its rapport with people.

## 7  CONCLUSION

In this work, we present a novel *companion-like* robot that delivered interactive positive psychology interventions along with other useful skills during the COVID-19 pandemic. Our long-term deployment study showed that a social robot delivered positive psychology sessions were effective at improving people's psychological well-being, affect, and motivation for behavior change, and that the effect was greater when users have built therapeutic alliance with the agent. While both the robot's *coach-like* and *companion-like* interaction styles were effective, our results show that the *companion-like* robot style formed tighter working alliance with the users and produced the best intervention outcomes. These results suggest that it is important to design an interactive agent as a helpful and supportive companion that can build long-term rapport and therapeutic alliance in order to improve the efficacy of its health interventions. Our work contributes to studying how to design companion AI agents that can support people's long-term well-being goals in daily lives.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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## CCS CONCEPTS

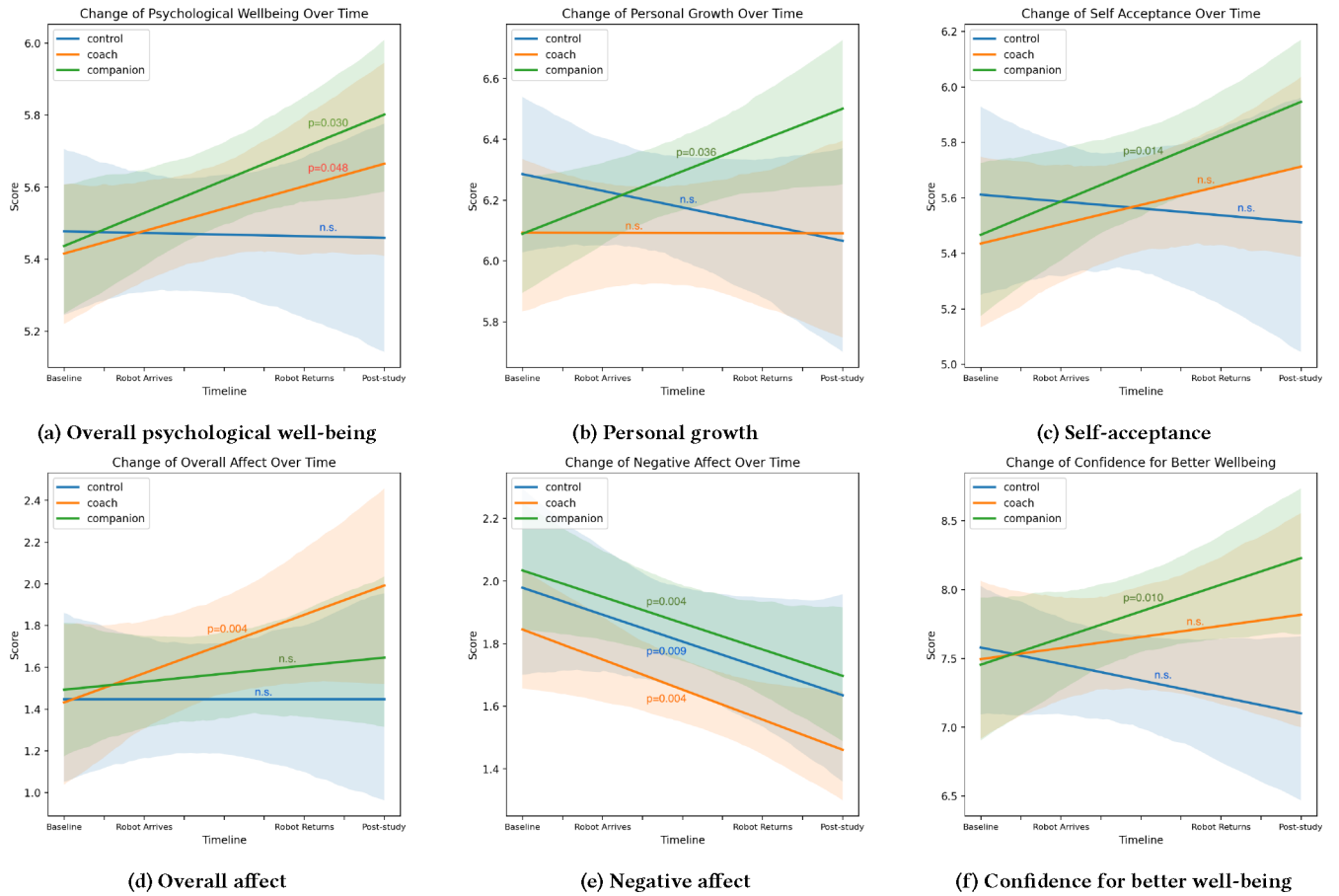• Human-centered computing → Empirical studies in HCI; Empirical studies in interaction design.
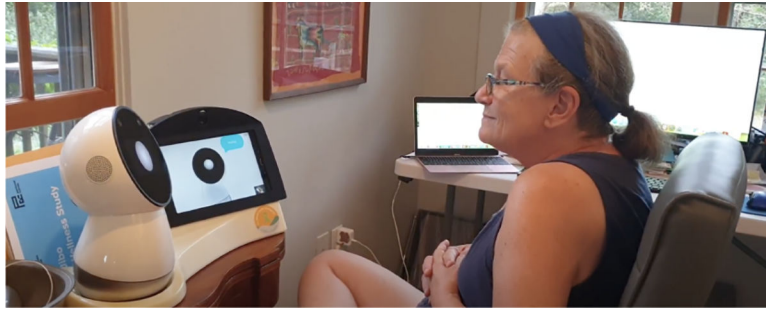
**Figure 1:**
Seventy participants (age 18–83; M=48.225, SD=23.374) lived with a robotic companion in their homes and learned about positive psychology interventions during an 8-week-long study.

(a) A portable robot station integrated a Jibo robot, Android tablet and Raspberry Pi with a USB camera.

(b) A study booklet, alcohol wipes, cleaning cloth, and a small notepad was sent along with the robot station.

**Figure 2:**
Study materials sent to participants' homes for the study.

(a) Overall psychological well-being

(b) Personal growth

(c) Self-acceptance

(d) Overall affect

(e) Negative affect

(f) Confidence for better well-being

**Figure 3:**
The *companion-like* condition showed a statistically significant improvement in overall psychological well-being, personal growth, self-acceptance, and confidence for better well-being. The *coach-like* condition showed significant improvement in overall well-being and overall affect. All three conditions showed significant reduction in negative affect. [Graph interpretation: increasing trend is better except negative affect, which decreasing trend is better.
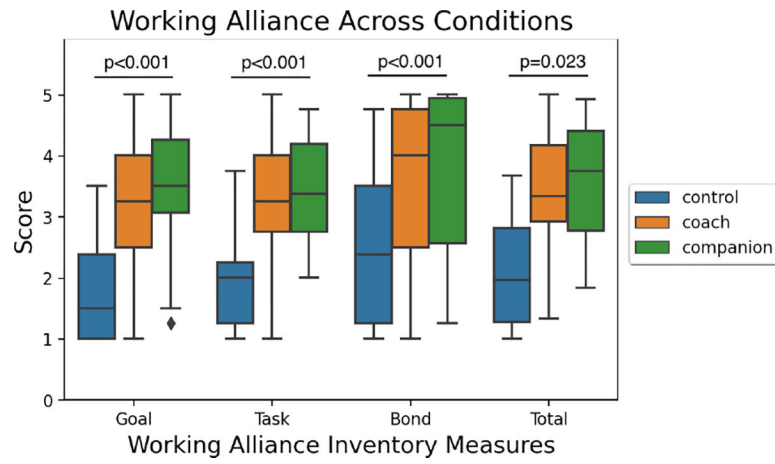
**Figure 4:**

Participants' working alliance with the robot showed statistically significant differences among the three experimental conditions.

**Table 1:**

Results from the linear mixed regression model. *Coef* refers to the coefficient value and *SE* is the standard error of the week term.

| Measurement | Control | | | | Coach-like | | | | Companion-like | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coef | SE | z | p | Coef | SE | z | p | Coef | SE | z | p |
| *RPWS_total* | 0.007 | 0.016 | 0.453 | 0.651 | 0.023 | 0.011 | 1.980 | **0.048*** | 0.033 | 0.015 | 2.167 | **0.030*** |
| *RPWS_A* | 0.008 | 0.021 | 0.387 | 0.699 | 0.049 | 0.030 | 1.618 | 0.106 | 0.029 | 0.027 | 1.087 | 0.277 |
| *RPWS_EM* | 0.028 | 0.036 | 0.793 | 0.428 | 0.027 | 0.027 | 1.000 | 0.317 | 0.037 | 0.030 | 1.246 | 0.213 |
| *RPWS_PG* | −0.025 | 0.018 | −1.388 | 0.165 | 0.003 | 0.024 | 0.136 | 0.892 | 0.038 | 0.018 | 2.092 | **0.036*** |
| *RPWS_PR* | 0.002 | 0.025 | 0.085 | 0.932 | 0.025 | 0.020 | 1.254 | 0.210 | 0.019 | 0.023 | 0.838 | 0.402 |
| *RPWS_PL* | 0.021 | 0.023 | 0.912 | 0.362 | 0.018 | 0.020 | 0.879 | 0.379 | 0.031 | 0.021 | 1.430 | 0.153 |
| *RPWS_SA* | 0.014 | 0.021 | 0.683 | 0.495 | 0.022 | 0.019 | 1.182 | 0.237 | 0.047 | 0.019 | 2.451 | **0.014*** |
| *PANAS_total* | 0.030 | 0.034 | 0.875 | 0.382 | 0.074 | 0.026 | 2.888 | **0.004**** | 0.019 | 0.027 | 0.690 | 0.490 |
| *PANAS_PA* | −0.019 | 0.022 | −0.844 | 0.399 | 0.019 | 0.020 | 0.919 | 0.358 | −0.017 | 0.019 | −0.868 | 0.385 |
| *PANAS_NA* | −0.050 | 0.019 | −2.620 | **0.009**** | −0.050 | 0.017 | −2.881 | **0.004**** | −0.036 | 0.013 | −2.852 | **0.004**** |
| *RR_imp* | −0.018 | 0.052 | −0.336 | 0.737 | −0.027 | 0.038 | −0.724 | 0.469 | 0.043 | 0.040 | 1.065 | 0.287 |
| *RR_conf* | −0.016 | 0.054 | −0.288 | 0.773 | 0.025 | 0.051 | 0.498 | 0.618 | 0.105 | 0.041 | 2.584 | **0.010*** |

**Table 2:**

Spearman's correlations between participants' working alliance and study outcomes.

| WAI_SF Item | Study Outcome | $\rho$ | p-value |
|---|---|---|---|
| W AI_goal | RPWS_total | 0.302 | **0.038*** |
| | PANAS_total | 0.043 | 0.773 |
| | RR_imp | −0.015 | 0.916 |
| | RR_conf | 0.065 | 0.663 |
| W AI_task | RPWS_total | 0.337 | **0.020*** |
| | PANAS_total | 0.257 | 0.080 |
| | RR_imp | 0.071 | 0.634 |
| | RR_conf | 0.161 | 0.277 |
| W AI_bond | RPWS_total | 0.169 | 0.256 |
| | PANAS_total | 0.012 | 0.932 |
| | RR_imp | −0.084 | 0.572 |
| | RR_conf | 0.070 | 0.637 |