Socially Assistive Robots and Their Applications on Mental Illnesses

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Abstract

More than 700,000 people die due to suicide every year[1]. Over the years, mental health has become a growing concern worldwide, leading to rising demand for therapists in the mental health industry. New treatments for mental health issues, including depression and anxiety, have been developed to meet this growing demand. The present study analyzes Socially Assistive Robots (SARs) supporting young adults with depression and anxiety, specifically the PlantBot and MARCo robots. We conclude that the ideal robot would use both Cognitive Behavioral Therapy (CBT) and Behavioral Activation Therapy (BAT) to support users in performing tasks and reaching goals. With further expansion of the use of socially assistive robots in the mental health field, a weight may lift on the growing demand for therapists.

Introduction

Suicide is the fourth leading cause of death among 15-19-year-olds worldwide, with 40% of these suicides caused by anxiety and depression[1]. Despite this endemic of mental illness, globally, only 2 percent of government health budgets go to research on mental conditions and their treatments. An even smaller fraction of this sum focuses specifically on adolescents[2]. Understanding the mechanisms underlying mental illness and effective treatments seems particularly necessary in adolescents considering half of mental illnesses begin by age 14 and three-quarters by age 24[3]. Due to the growing call for mental health support, therapists are in high demand. However, there are insufficient mental health professionals available to handle this crisis. When the American Physiological Association surveyed its members in the fall of 2021, it found that 62% of psychologists saw a surge in new referrals. Moreover, 65% of psychologists had no capacity for new patients, and 68% reported longer waitlists compared to 2020[4].

In recent years, novel technologies have developed to subsidize the need for mental health professionals. For example, Socially Assistive Robots (SARs) are interactive devices that use typical therapeutic strategies to support patients and therapists through Artificial Intelligence technologies[5]. SARs exhibit natural-appearing social qualities, such as basic conversation or movement, and assist human users through therapeutic sessions[6]. SARs utilize many therapeutic strategies, including Cognitive Behavioral Therapy (CBT) and Behavioral Activation Therapy (BAT). CBT is talk-based therapy designed to counteract problematic or unhelpful patterns of thoughts and behaviors. Therapists speak to patients and help them analyze their views of themselves while teaching them positive habits for dealing with numerous mental illnesses, such as anxiety and depression[7]. BAT attempts to counter negative patterns in mentally ill patients, such as general inactivity and avoidance[8]. By assigning simple tasks, such as speaking to a family member, participating in a community event, or cleaning their room, BAT encourages the patient back into their pre-depression lifestyles. BAT often uses outside family members or friends as tactics to further give positive encouragement in completing these tasks[8]. Thus, SARs represent an alternate or supplemental option for those without access to adequate medical and mental health treatment, allowing for an accessible option for young adults. However, it is essential to note that SARs are not an approved treatment by most health organizations.

PlantBot

Plantbot, a plant-shaped SAR, works with therapists to help patients with anxiety or depression[9]. The SAR, designed by students at the University of Twente, helps patients complete their therapist-assigned BAT tasks[9]. Using a microcontroller-based mechanical design and Amazon Alexa voice assistant within a plant-shaped device, PlantBot sets up a series of studies and rewards to motivate its patients. PlantBot's plant shape design allows the user to bond with the PlantBot as a living creature needing care for its survival. The plant-shaped design of the PlantBot incorporates Horticulture Therapy, which is effective for some patients suffering from depression and anxiety, giving a nurturing, calming effect as they care for their plants[10]. Ultimately, PlantBot aims to provide a welcoming option to remind young people to complete their therapy assignments.

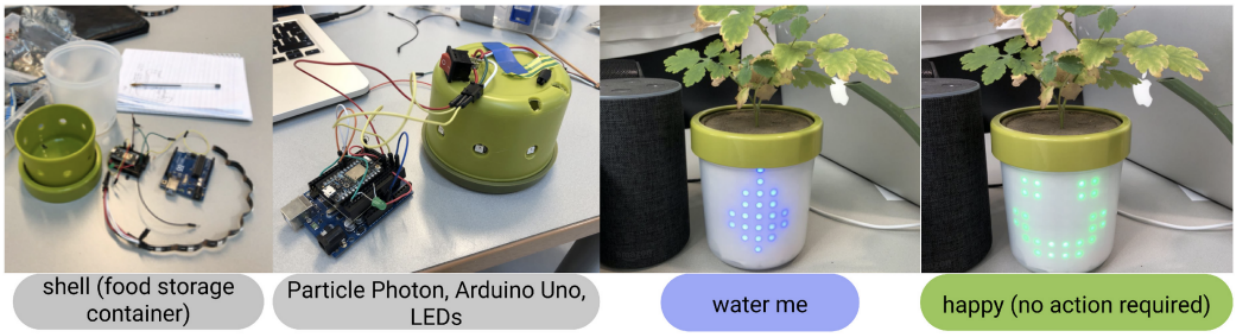

Figure 1: Images of PlantBot design. From left: Shell, electrionsics, water drop emoticon, and happy face emoticon.[9]

Design

PlantBot uses question-based software to guide users through tasks using questions with limited responses[9]. Assignments range from personal tasks, such as listening to music, to accomplishment-based tasks, such as homework. These tasks have two categories: pleasurable and valuable. Pleasurable tasks primarily encourage happiness by initiating activities that bring the user joy[9]. Thus, they are usually highly personal and customized to each individual. Practical tasks target a sense of accomplishment and are more general across users[9].

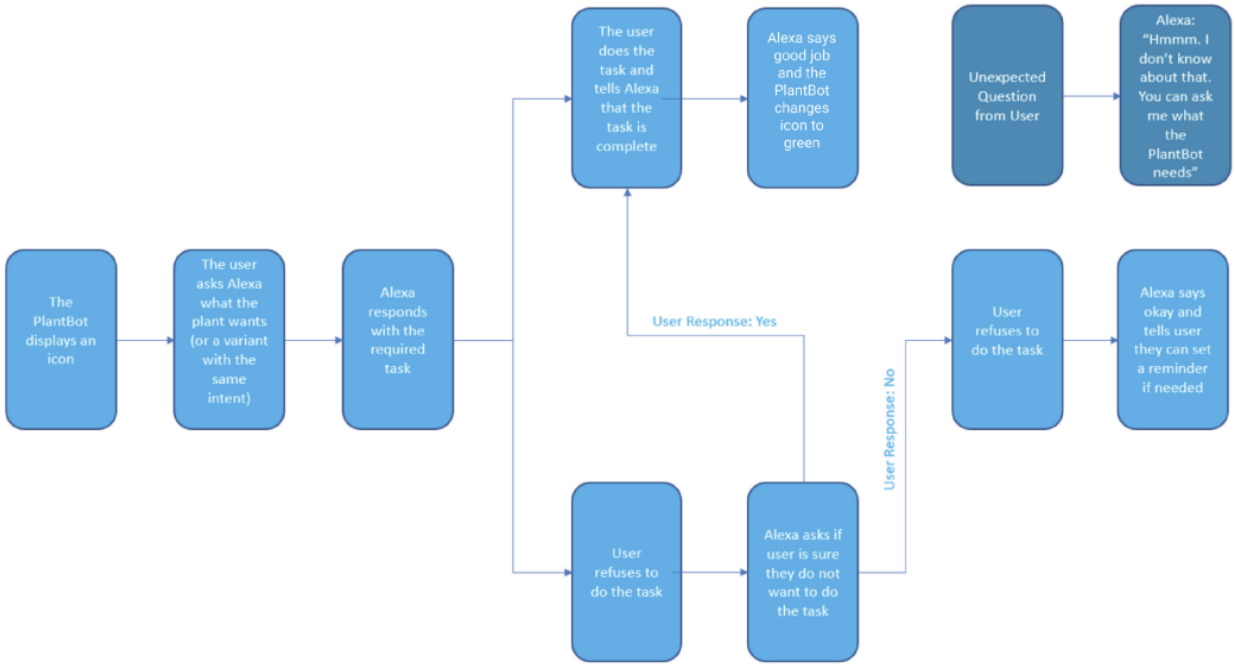

Figure 2: Flow chart representing how PlantBots question software works[9]

LED symbols on the pot of the PlantBot indicate when it is time to complete a task, the "emotional" state of the robot, or an incoming question for the user. These markers (water droplet, happy emoticon, question mark, sad emoticon, heart icon) all help bring the robot to life and actively involve the user in its newly assigned tasks[9]. The water droplet symbolizes that the plant needs water. The happy and sad emoticons indicate that a task is complete or the user has refused to finish a task. The question mark indicates the robot has a task for the user and the heart icon informs the user they have completed multiple tasks[9].

The PlantBot design uses two rapid prototyping boards to support these functionalities: a Particle Photon and an Arduino. Each board allows for a mixture of tasks that help program, store data, and allow for the general use of the robot. For example, the particle photon enables the robot to attach to Wifi for Amazon Alexa, while the Arduino Uno provides the heart of the programming or the central control algorithms[9].

Device Analysis

The PlantBot underwent three tiers of testing and analysis: a review from a domain expert, an in-person test, and an online survey of users. The domain expert, a professor from the University of Twente, approved the design of the robot, suggesting that using a plant design would allow it to pass as a decorative item. An inconspicuous treatment device might appeal to those who prefer to keep their mental health status private. Besides the design of the robot, the domain expert believed that using icons and badges would bring a rewarding sense of satisfaction to the user but recommended improving the rewards system by making the user customize their rewards or put in a point-based system. Some examples of prizes would be playing their favorite song or unlocking hidden features in the program. These rewards would

further motivate the user to complete their assigned tasks. Overall, the therapist saw value in the design and general use of the robot.

For in-person testing, the creators of PlantBot recruited 20 students from the University of Twente to test PlantBot through a series of simulations. The simulations evaluated two characteristics of the PlantBot: its effectiveness in managing depression symptoms and the design of the robot. Participants who reported past depression symptoms provided data on both traits, whereas those not questioned about their history of mental illness contributed to just the latter. With the data gathered by the participants, the designers of PlantBot concluded that there remains a large room for improvement around the general structure of the robot, including consistent confusion on what the different emoticons meant and the fact that many participants found it strange that Alexa and PlantBot were two separate entities[9].

In-person testing revealed that the primary weakness of PlantBot is its design. Many participants needed clarification on the simulation and questioned the usefulness of the robot's tasks[9]. Users also worried about how the robot would fit within their lifestyle and whether it might interrupt them during school or important events[9]. However, this issue is fixable by implementing a sleep mode, where the user tells the robot that they cannot perform a task for a specific period.

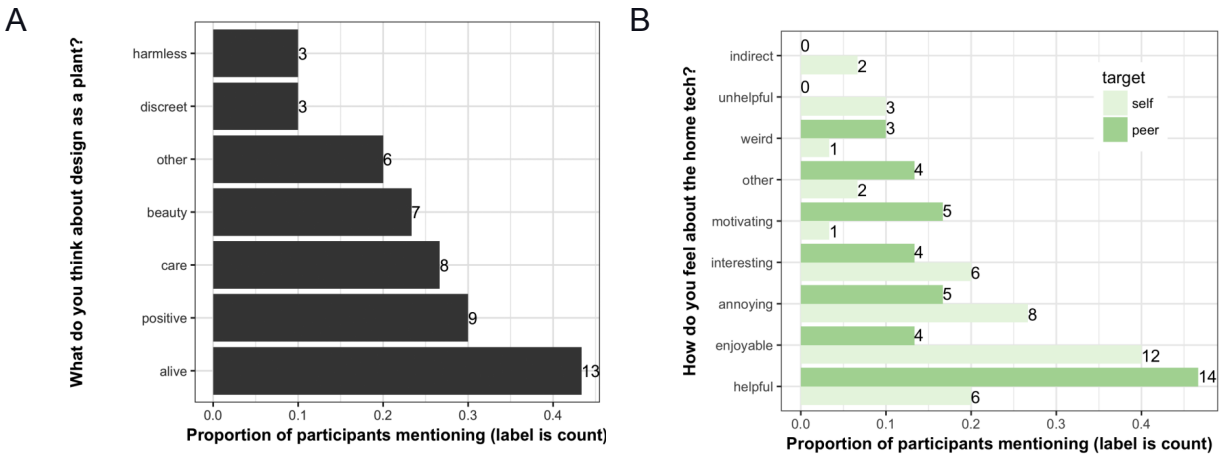

Figure 3: A Proportion of participants mentioning opinions on design of PlantBot[9]
B Proportion of participants mentioning opinions on their feelings or theoretical peers feelings towards PlantBot[9].

Finally, after creating the initial design of PlantBot, it was evaluated by surveying patients online to gain insight into how adolescents experience depression[9]. The online survey aimed to identify how PlantBot could assist users with depression. Participants were between the ages of 18-26 and had been diagnosed with depression[9]. The survey followed a peer-to-peer setup that would ask the tester about themselves and their opinion of a separate user[9]. These questions included:

1. Would you/do you think people with depression would make the requests made by the home technology shown in the video?
2. What do you think about designing home technology to look like a plant?

3. Do you have any suggestions for the home technology demonstrated in the video?
4. How do you/how do you think people with depression would feel about the home technology demonstrated in the video?

Most participants reported that the plant felt alive, and some indicated the PlantBot'sdesign as positive (Fig. 4). Furthermore, most peer responses indicated that peers would find the technology helpful. Most of the self-response reported that participants with depression would find the technology enjoyable[9].

After completion of the testing, PlantBot seems to have succeeded in its goal to provide a practical and positive design to support patients in completing their BAT tasks. Many users report that the overall design and purpose of PlantBot could ultimately help those dealing with depressive symptoms[9]. Furthermore, the domain expert's analysis of the robot suggests that it can provide structure for patients to complete their therapist-assigned BAT tasks between therapy sessions[9].

Due to its plant shape design and type of programming, PlantBot is minimally intrusive into a person's daily lifestyle beyond therapeutic interactions. Furthermore, there are some benefits to the robot focusing on a single type of therapy; because the robot only focuses on BA therapy, the designers of PlantBot can expand on BA therapy more without having to worry about the limitations of the programming data collection and processing system. Bypassing these limitations would allow PlantBot to incorporate more intricate tasks and rewards that cater to each user. However, it is generally better to have a broader range of practices to help multiple types of patients; since individual people require different forms of support.

MARCO

The Mental Health Assisting Robot Companion (MARCo) is a mental health robot designed by Jacob Boyle and tested at the College of New Jersey to support patients through CBT, BAT, and mindfulness training[11]. MARCo aims to help improve patients' moods, reduce stress, and approach anxiety by acting as a peer to listen to and comfort the patient[11]. The robot focuses on supporting patients not dealing with chronic mental illnesses. MARCo's design focuses on comfort; it is covered in padding and easily movable. MARCo uses AI and language-based programming to analyze the user and provide treatment based on the results[12]. MARCo technologies aim to supplement or replace traditional psychological therapy, thus increasing the quality and accessibility of mental healthcare[11].

The ultimate goal of the MARCo is to provide a low-cost robot "friend" so that anyone struggling with anxiety, depression, or general mental issues can have support whenever needed. However, MARCo technology primarily targets users aged 14 to 24, a crucial age for developing chronic mental illnesses[13]. MARCo aims to prevent the further development of mental illnesses by providing preventative treatment[11].

Figure 4: Photo of MARCo[11]

Design

Users initiate a conversation with MACRo by pressing a button on the robot's hand, opening the MARCo app, or logging on to the website. MARCo's programming will hold a conversation for however long the user needs, using advanced programming language technology. Users can communicate with MARCo using the chat box or listening modes[11]. The chatbot structure enables MARCo to understand short speech and text through the app or website, allowing the user to get in touch with MARCo even if they cannot access the robot. For a conversation in person, MARCo takes in the user's words, analyzes the speech, and identifies specific keywords to find patterns and select an appropriate response[14]. The AI technology tracks the patient's mental state and mood using natural language processing technology to analyze their conversation, searching for keywords or categories that would trigger a select response[14]. To aid users through crises, MARCo has five objectives of care: companionship module, Guided Meditation, and Destress Modules Talk Support Module, Biofeedback, and High Alert Outreach[11].

The Companionship module focuses on encouraging activities the robot provides to achieve individual goals, such as the mental health scavenger hunt or various wellness activities[11]. Guided Meditation and Destress modules help to calm the users during stressful times or teach them healthy ways to deal with that stress or anxiety[11]. In the Talk Support Module, MARCo facilitates a therapy session using AI-driven CBT with the user[11]. The Biofeedback Module identifies the user's immediate mood using heart rate and facial expression data, which is uploaded into the robot’s AI system to help tune its responses. MARCo analyzes a patient's sleeping, eating, and exercising habits over time to understand the patient's long-term mental state[11]. Lastly, the High Alert Module is triggered when the patient is at risk of suicide or self-harm. High alert outreach uses the Colombian Suicide Rate Scale to quantify the

severity of the user's intent to harm. It then contacts the user's emergency contacts and suggests a course of action[11].

According to Boyle, the preliminary design of the MARCO robot was chosen based on extensive reviews from hundreds of students across the United States[15]. During interactions with the user, the robot asks a question and formulates a response using its internal algorithm. To train the AI algorithm, professional psychologists analyzed questions the robot would ask, predicted general responses, and programmed appropriate responses to the patient[15].

Data Analysis

Due to using AI algorithms, MARCO's programming is more complex than Plant Pots. Thus, MARCO could provide a more robust dialogue and experience for the user. In addition to employing standard CBT and BAT techniques, MARCO adapts to each user to provide a highly individualized experience. However, the company has not released testing methods and data, raising the question of the efficacy of using MARCO to support users with depression and anxiety. Theoretically, the robot's overall design and AI system might be effective for users with depression and anxiety; however, published data is necessary to quantify MARCO's effectiveness.

Furthermore, the company's privacy policy is not comprehensive and does not explain the ownership of data collected by users. The company collects some primary data, such as names and emails but states that they do not sell personal data to outside sources. However, the privacy policy is vague regarding data from interactions with the user; for example, it neglects to give exact details as to where the biofeedback and conversational data are stored.

Discussion

As mental health, specifically anxiety and depression, among young adults further develops across the globe, engineers and researchers continue to look for new methods to help counteract this issue. One approach has been the development of SARs, such as PlantBot and MARCO. SARs have the advantage of an AI system, allowing the robots to grow and learn. Furthermore, SARs can further monitor a user's situation and notify emergency contacts or medical professionals in the event of declining mental health or an emergency. However, SARs are limited by funding, general research, and access to technology. Following the rectification of limitations due to being early in the development process, SARs could become a new alternative for young adults seeking mental health support, allowing for more advanced health monitoring technology.

SARs have grown in popularity in recent years, leading to new developments of different kinds of robots. Future robots might benefit by combining the AI technology in MARCo, with PlantBot's more detailed use of BAT. To add on, other therapy techniques, such as CBT, give a more generalized software decision capable of morphing to the patient's specific needs.

Between PlantBot and MARCo, the most optimal SAR robot is MARCo. However, future designs of MARCo could benefit from implementing a clear privacy policy that helps the user and adding more BAT features. For example, providing tasks, the patients must follow to maximize the potential uses the robot can provide for the patients. One of the more concerning issues in SARs is their privacy policies. Since SARs collect massive amounts of personal data, future developments of SARs could partner with hospitals to protect a user's privacy. Thus, any data collected by the robot would be under patient privacy policies in hospitals, which are extensive. Having SARs follow hospital/health patients' privacy policies would ensure more

advanced security measures within the robot and allow the robots to undergo further testing to ensure they work properly.

SARs are a new solution to address the deficit of mental health robots. Therefore future research is necessary to determine the effectiveness of using SARs to treat mental illness in adolescents. Furthermore, the proprietary nature of SARs as patented products limits the available data for the robots' design, programming, and effectiveness.

References

[1] *Suicide*. (2021, June 17). Retrieved October 20, 2022, from https://www.who.int/news-room/fact-sheets/detail/suicide

[2] *WHO report highlights global shortfall in investment in mental health*. (2021, October 8). Retrieved October 20, 2022, from https://www.who.int/news/item/08-10-2021-who-report-highlights-global-shortfall-in-investment-in-mental-health

[3] *Home | NAMI: National Alliance on Mental Illness*. (n.d.). Retrieved October 20, 2022, from https://www.nami.org/Home

[4] *Worsening mental health crisis pressures psychologist workforce*. (2021, October 19). American Physiological Association. Retrieved October 20, 2022, from https://www.apa.org/pubs/reports/practitioner/covid-19-2021

[5] Dove Press. (2018, June 14). Socially assistive robots: current status and future prospects for aut | IEH. https://www.dovepress.com/socially-assistive-robots-current-status-and-future-prospects-for-auti-peer-reviewed-fulltext-article-IEH

[6]Scheutz, M. (2020). Assistive Robots for the Social Management of Health: A Framework for Robot Design and Human–Robot Interaction Research. International Journal of Social Robotics, 13(2), 197–217. https://doi.org/10.1007/s12369-020-00634-z

[7] *What is Cognitive Behavioral Therapy?* (2017, July). American Physiological Association. Retrieved October 20, 2022, from https://www.apa.org/ptsd-guideline/patients-and-families/cognitive-behavioral

[8] Villines, Z. (2021, October 25). *What is behavioral activation?* Retrieved October 20, 2022, from https://www.medicalnewstoday.com/articles/behavioral-activation

[9] Bhat, A. S., Boersma, C., Meijer, M. J., Dokter, M., Bohlmeijer, E., & Li, J. (2021, September 30). Plant Robot for At-Home Behavioral Activation Therapy Reminders to Young Adults with Depression. *ACM Transactions on Human-Robot Interaction*, *10*(3), 1–21. https://doi.org/10.1145/3442680

[10] EnviRobots: How Human–Robot Interaction Can Facilitate Sustainable Behavior. (2021, November 7). *Sustainability*, *13*(21), 12283. https://doi.org/10.3390/su132112283

[11] MARCo – Your Mental Health Companion. (n.d.). Retrieved October 27, 2022, from https://www.marcohealthtech.com/

[12] Michael L. Diamond, Asbury Park Press. (2022, May 11). Therapy with a robot? How AI could help those struggling with mental health. Asbury Park Press. https://eu.app.com/story/news/health/2022/05/11/therapy-robot-mental-health-tech-nj-startup/9648028002/

[13] Half of all mental illness begins by the age of 14. (2020, February 7). World Economic Forum. https://www.weforum.org/agenda/2018/10/half-of-all-mental-illness-begins-by-the-age-of-14/

[14] Contreras, C. (2022, June 11). Marco Technologies CEO Jacob Boyle aims to make a difference with Mental Health Service Robot. Robotics 24/7. Retrieved November 19, 2022, from https://www.robotics247.com/article/marco_technologies_ceo_jacob_boyle_aims_to_make_a_difference_with_mental_health_service_robot

[15] YouTube. (2022). Techstination Interview: A robotic mental health companion for students from #MARCo Technologies. YouTube. Retrieved November 19, 2022, from https://www.youtube.com/watch?v=Imweogmjwr8.