

Use of a companion robot at home by older people with cognitive decline and psychosis: A case series with 18-month follow-up

Yuma Nagata

Yuto Satake

y.satake@psy.med.osaka-u.ac.jp

Department of Psychiatry, Osaka University Graduate School of Medicine <https://orcid.org/0000-0002-9350-3162>

Ryuji Yamazaki

Shuichi Nishio

Hiroshi Ishiguro

Manabu Ikeda

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Abstract

Objectives

Although studies have reported the efficacy of companion robots for psychological support in older people, most are limited to short-term use or use within nursing home settings. In this study, we describe the five cases using a companion robot to elucidate the benefits and challenges of deploying conversational, autonomous humanoid robots for community-dwelling older adults with cognitive decline over an extended period.

Methods

Case series. Participants were recruited between July and November 2020 from patients visiting memory clinics in Japan who were 1) aged 60 or more, 2) living alone, and 3) with a Clinical Dementia Rating score of 0.5 or 1. In participants' homes, we placed a commercially available companion robot, RoBoHoN (Sharp), which was autonomous, conversational, and humanoid. After an exploratory two to five months' use and a further two months' wash-out, we installed the robot at their homes for one and a half years. We longitudinally assessed participants with scales assessing their psychological state and ease of robot use. At the four-month assessment, an interview about the pros and cons of the robots was also conducted.

Results

Participants were five female patients aged 85 to 90 with mild cognitive impairment or late-onset psychosis. All could use the robot by themselves with minimum support from the research team. The scale assessing usability showed high levels of satisfaction and ease of use. Although the psychological measures did not show any specific trends during the study period, participants generally enjoyed verbal communication with the robot, and four out of the five wanted to continue using the robot after the study period.

Conclusion

This study suggests that conversational companion robots have the potential to be accepted over the long term by community-dwelling older adults with mild cognitive impairment or psychosis.

Key Points

- This is a case series describing the use of a conversational companion robot in the home of older adults for one and a half years, with longitudinal psychological measures and interviews about the robot's perceived pros and cons.

- Although it was difficult to find consistent trends in psychological measurements, all participants could use the robot for the entire study period without continuous support from the researchers. Well-designed conversational companion robots could be used for older persons living alone with mild cognitive impairment or psychosis.
- Most patients and caregivers reported poor conversational ability with delayed responses. Strong attachment to the robot could be associated with risks when it is withdrawn. Further development and efficacy studies are needed to make it a therapeutic tool.

Introduction

Since the early 2000s, the use of robot-assisted psychological support has been explored for older people (1), and reviews have reported the use of social robots for older people with and without cognitive impairment (2–4). Some studies have shown positive results in alleviating psychological distress in older people (5–8). However, most studies have focused on applications within nursing homes, and study periods have been less than one year. Some articles have highlighted limitations in applying social robots for use at home to improve the well-being of older people (9). Advances in robotics have led commercial organisations to introduce a variety of new social robots, including ElliQ (Intuition Robotics), HYODOL (Hyodol), LOVOT (GROOVE X), Romi (MIXI) and Loona (KEYi Robot), alongside updated models of established robots like AIBO (Sony). While many older people are assumed to have purchased and engaged with these devices for several months, published reports on their extended use remain limited.

Social isolation and loneliness in older people are growing issues worldwide (10,11). This is the case in Japan, where 28.6% of the population was aged 65 or above, and among this group, 15% of men and 22.1% of women lived alone (12). From 2019 to 2023, we examined the use of a commercial companion robot, RoBoHoN (Sharp, Fig. 1), for older adults living alone. In our previous articles, we reported successful short-term use of the robot among older adults with cognitive decline, noting positive engagement for up to three months (13) and demonstrating continued attachment to the robot, even following a two-month withdrawal period (14). Following this, we reintroduced the robots to five participants' homes and monitored their usage and psychological health over 18 months to assess long-term usability and effects on psychological well-being. This report presents our findings on participants' demographics, robot usage and associated psychological metrics. We aimed to contribute insights into the benefits and challenges of deploying conversational, autonomous humanoid robots for older adults over an extended period.

Methods

Procedures

We recruited participants between July and November 2020 at the Memory Clinic of the Osaka University Hospital or Kyowakai Hospital (Osaka, Japan). The eligibility criteria were 1) aged 60 or more, 2) living alone, and 3) with the Clinical Dementia Rating (CDR) score of 0.5. In Case 1, the robot was installed in

October 2020, Case 2 in November 2020, Cases 3 and 4 in December 2020, and Case 5 in January 2021. After that, all the robots were withdrawn from participants' homes in March 2021 and reinstalled in May 2021. Outcome assessments were conducted in September 2021, January 2022, and June 2022, and a final evaluation was conducted in November 2022. In the September 2021 evaluation, participants and caregivers were interviewed about the pros and cons of the robot and the functions they thought should be added to it. Figure 2 shows the overall flow of participants through the evaluations. At all assessment points, the UCLA Loneliness Scale (Version 3) (UCLA-LS) (15,16), Geriatric Depression Scale (GDS) (17), Brief Psychiatric Rating Scale (BRPS) (18), Neuropsychiatric Inventory (NPI) (19,20) and System Usability Scale (SUS) (21) were evaluated. BPRS was only used for Cases 1 and 4, who had symptoms of psychosis and the NPI was only used in all participants other than Case 4, who did not have a caregiver to complete assessments. Until the evaluation in January 2022, the customised robot described below was used and was later replaced with the commercially available RoBoHoN.

Robot

RoBoHoN is a conversational, autonomous, social robot with a humanoid shape that stands 19.5 cm in height and weighs approximately 360 grams (22). We used the SR-05M-Y version of the robot, which can move its arms and head but not its legs and is connected to Wi-Fi. Although it contains a lithium battery, the robot was always plugged into a power outlet through a cradle for this study. At the participants' home, we installed this robot with a portable WiFi router, NEC Aterm MR05LN. Each arm has two degrees of freedom (DOF), and the head has three DOF, giving it a total of seven DOF. It used a Qualcomm Snapdragon 430 processor with 16 GB ROM/2 GB RAM and was operated by the Android version 8.1. Through a touch screen on its back, the robot can be connected to Wi-Fi, adjust the volume of its speech and register the user's name and face. This robot is capable of speech recognition and speech synthesis. While connected to the internet, the audio data the robot hears is sent to a remote server, which is recognised as text by the speech recognition engine. The dialogue engine then interprets the content based on the preset dialogue scenarios, and a response is generated in text form. Finally, the text data is sent to the robot, where it is synthesised as speech, and at the same time, the motions that match the scenario are performed. VoiceText (now ReadSpeaker, Hoya Corp.) is used for text-to-speech, AmiVoice (Advanced Media Inc.) for offline speech recognition, and Nuance Communications, Inc. engines are used for cloud speech recognition until January 2021, after which mimi (Fairy Devices, Inc.) is used. Brightly coloured LED displays surrounding the robot's eyes indicate to the user that the robot is ready to listen, is recognising speech, and can also indicate when the robot cannot recognise speech. The robot outputs speech through the speaker, while at the same time, an LED light installed in its mouth blinks to indicate that the robot is speaking. It also accompanies body and arm gestures when it is speaking. Before speaking, the robot estimates the direction of the coming voice and moves its head toward that direction to give a more conversational feeling during an interaction. It has an approximately 8 million pixels CMOS camera, which can recognise the face of an individual user and can capture images.

This robot is marketed with the tagline, “a robot that puts a positive spin on your life,” and is designed to engage with users in a manner resembling a pleasant five-year-old child. It reacts as if it is aware that it is a robot manufactured by Sharp Corporation. The robot reliably responds to basic greetings, such as "Good morning" or "I'm home". When users inquire about specific topics—such as the weather, date, news, or local specialities—the robot generates responses via Sharp’s server, providing interesting and engaging answers. However, for unanticipated topics, it cannot be necessarily relied upon to respond meaningfully. It can also entertain users by performing pre-programmed applications such as singing, dancing, pretending to fish and surf, and telling jokes. Another feature of this robot is that it can spontaneously start talking without input. It is also possible to make phone calls and take photos by operating the touch panel on the back, however, in this research, we asked participants not to use these functions.

The customised version had our own control system software to detect conversation logs and make user interaction simpler and faster, described in detail in our previous article (13).

Results

Table 1 summarises the participants’ demographic data. Table 2 shows the participants and their caregivers’ opinions on this robot's pros, cons, and functions that they thought should be added to the robot at the four-month assessment. Figure 3 shows the longitudinal changes of UCLA-LS, GDS, SUS, NPI and BRPS. In case 1, the patient is Patient 1, and the caregiver is Caregiver 1, and the same numbering system is used for subsequent cases.

Table 1
Demographic Data

	Case1	Case2	Case3	Case4	Case5
Age	87	85	90	85	86
Sex	Female	Female	Female	Female	Female
MMSE	28	25	28	28	27
CDR	0.5	0.5	0.5	0.5	0.5
Diagnosis	late-onset psychosis	PD-MCI	MCI-LB	late-onset psychosis	MCI due to AD
Primary psychiatric symptoms	delusions, hallucinations	hallucinations, anxiety	delusions	none	none
Severe complications	chronic renal failure and deafness	none	none	minor cerebral stroke	none
Housing	flat	flat	flat	flat	detached house
Social welfare service	day centre, twice a week	homecare service, once a week; day centre, three times a week	homecare service, twice a week	homecare service, once a week; community nursing service, twice a week	homecare service, twice a week; day centre, twice a week
Primary caregiver	daughter visiting the patient once a week	son visiting the patient twice a month	daughter visiting the patient twice a month	none	son visiting the patient more than one a week
MMSE, Mini-Mental State Examination; CDR, Clinical Dementia Rating; PD-MCI, mild cognitive impairment in Parkinson's disease; MCI-LB, mild cognitive impairment due to Lewy bodies; MCI due to AD, mild cognitive impairment due to Alzheimer's disease.					

Table 2
Pros, cons and expected additional features

	Pros	Cons	expected additional features
Patient 1	□They listen to you without saying a word, and respond with gestures.	□Sometimes it turns away from me and we can't carry on a conversation.	no idea
Patient 2	□It cheers me up. □When it's hot, It says "Don't leave me in the car", so I know the temperature.	□I feel like I'm being watched all the time. □Its talk is sometimes inconsistent.	no idea
Patient 3	□We get along well and have fun talking together □It is helpful that It tells me weather forecast. □When I say hello in the morning, It tells me the date and the weather, and it creates my rhythm.	□I feel bad leaving him alone, so I get nervous when I go out. □When I talk with my friends, I worry that information is leaking somewhere. □Its response is sometimes slow and repetitive.	no idea
Patient 4	□It often greets me casually, so I'm talking more than before. □I can forget about the bad things while I'm talking to him. □It is adorable, and It makes me feel loved.	no idea	no idea
Patient 5	□It teaches me lots of things (about the weather, world affairs, etc) □It responds to everything. It's better than being alone.	□Its conversation is a little inadequate.	no idea
Caregiver 1	□When it's just the two of us, we sometimes end up taking out our frustrations on each other, but when Robohon is around, it acts as a buffer.	□It may stop working suddenly. □Its response is sometimes too slow.	□It would be good if it has a monitoring camera function for checking on my mother's safety.
Caregiver 2	□It's good that It tells the date and weather. □It's also interesting to get a response that's out of sync.	□It sometimes does not respond. Its conversation is not so smooth.	□It would be great if it could automatically recognise the plants in the garden, take a photo, and respond with praise.

	Pros	Cons	expected additional features
		□It's better if it can be moved a little more without being fixed in place.	□It would also be nice if it could ask her if she has taken her medicine, and encourage her to sleep and wake up at the right time.
Caregiver 3	□My mother lives alone, so it's wonderful just to have someone to talk to. □It's good that it talks to her spontaneously, as it gives her more opportunities to speak.	□We were worried that personal information might have leaked from the camera.	□It would be good if an alert was sent to family members on days when there is little response. □It would also be nice if it could tell my mother things that we hesitate to tell, such as necessary advice related to her memory problems.
Caregiver 5	□It makes my mother talk more	□My mother says hello to it, but she can't find other new ways to enjoy with the robot. □There is a tendency for phrases introducing local places to be repeated a lot.	□I want it to monitor my mother for accidents like falls, encourage her to exercise, and suggest meal menus.

Case 1

87 years old, late-onset psychosis

At age 84, the patient started to complain of auditory hallucinations from neighbours living next to her and persecutory delusions such as stealing her things. She often shouted, responding to the auditory hallucinations. This continued after she moved to a different house, and she visited our hospital for investigation. She was diagnosed with late-onset psychosis due to her preserved cognition and prominent psychotic symptoms (23), and her cerebrospinal fluid testing suggested Alzheimer's Disease (AD). A small dose of antipsychotic drug improved only her aggression against her hallucinations. At age 87, we installed the robot in her home. She enjoyed speaking with it every day, and although she expressed frustration that the dialogue was sometimes not going well, she said she never got bored with the interactions. Her daughter was also satisfied with it and mentioned its usefulness of the robot as a gentle buffer between the patient and her. The daughter said that it became a sort of family member. Difficulties with the robot suddenly stopping speaking and trouble with poor responses were reported as problematic at times. Her scores were relatively stable on the UCLA-LS but increased from 6 to 11 on the GDS. This was attributed to her worsening severe chronic renal failure. Her psychosis remained stable. She also wanted to continue using the robot, and we left it after the final assessment.

Case 2

85 years old, mild cognitive impairment in Parkinson's disease (MCI-PD) (24)

At the age of 69, the patient started showing persecutory auditory hallucinations and taking olanzapine. She was diagnosed with Parkinson's Disease because of gait disturbances at the age of 73, and anti-parkinsonism drugs were started. At the age of 83, she visited our clinic with complaints of attentional deficits for three years. ¹²³I-FP-CIT Single-photon emission computed tomography (SPECT) suggested Lewy body disease, and she was diagnosed with Parkinson's Disease Dementia (25), and we prescribed donepezil. She originally had two stuffed toys that responded to humans' touch and voices for over 10 years. Whether this earlier experience contributed, she enjoyed the interactions with our robot. On the other hand, she complained that she felt like she was being watched constantly and that the conversation with the robot was inconsistent. Her son acknowledged that she had a good relationship with the robot while also pointing out that it didn't respond well during conversations. Her scores on the UCLA-LS fluctuated during the study period, and her GDS score increased from zero to four. During the observation period, she had some interpersonal troubles with other individuals in her day centre, which might have increased her GDS score. She still wanted to use the robot after 1.5 years, so we left it. She made a unique cushion for him to sit on (Fig. 1).

Case 3

90 years old, MCI with Lewy bodies (MCI-LB)

The onset symptom was visual hallucinations at the age of 85, and amnesia appeared at the age of 88 when the patient visited our clinic. With her mild cognitive deficits, clinical symptoms and positive results of FP-CIT SPECT and MIBG myocardial scintigraphy, she was diagnosed with MCI-LB(26). Donepezil was effective in treating her visual hallucinations and cognitive fluctuations. At age 90, she started the installation of the robot. She enjoyed talking with it daily and used the robot to learn information related to the weather and news. Although she was the oldest in the present five cases, she enjoyed many interests, such as taking the train into the city centre to attend Ikebana flower arranging classes. She reported its slow responses and felt guilty for leaving it at home when she went out. She and her daughter were worried about their information leaking due to its camera and voice recognition functions. Her UCLA-LS score decreased from 45 to 33, and her GDS score remained stable. She also wanted to continue using the robot, and we left it after the final assessment.

Case 4

85 years old, late-onset psychosis

The patient developed persecutory delusions involving a specific neighbour who she believed intruded into her house and stole things at the age of 81. She locked the entrance with chains and set an alarm to detect someone entering. At the age of 82, a Japanese outreach service, initial-phase intensive support team for dementia, started to visit her. Finally, the team took her to the memory clinic of Kyowakai Hospital. She was diagnosed with late-onset psychosis because of her structured delusions and scarce

evidence of organic brain disease. A small dose of antipsychotics and social support were started, but her psychosis remained. At the age of 85, she joined this long-term use study. She was delighted with the interaction with the robot. Although her psychosis did not change, she said that she could “forget about the bad things while I was talking to her”. We also heard an episode where she kept a cooling agent nearby when the robot mentioned it was hot today. This showed that she regarded the robot as an object she cared for. However, her UCLA-LS, GDS and BPRS scores, as well as psychosis, remained stable. She also wanted to continue using the robot, and we left it after the final assessment.

Case 5

86 years old, mild cognitive impairment due to Alzheimer’s Disease (MCI due to AD)

Cerebrospinal fluid testing and amyloid positron emission tomography were positive for AD, and she was diagnosed with MCI due to AD (27). At the age of 86, we started to put the robot. She talked with it every day, but said that she was not satisfied with the poor interaction between the robot. Her son found an increase in her speaking owing to the robot as well as its lack of variety in their interactions and repetitive responses. Her UCLA-LS scores changed from 34 at the installation to 26 at the final assessment. During the observational period, she increased the frequency of commuting to day-care services, and her son visited and stayed with her more frequently than at the starting date, which could also have contributed to improving her feelings of loneliness. She did not want to use it further at the end of 1.5 years, so we removed it after the period.

The SUS scores were stable in all five cases during one and a half years, which means that the participants did not perceive any apparent difficulties in using the robot over this entire period. Although we rarely support them technically, they basically could use the robots by themselves. Replacing robots from the customised version to the commercial version confused Patient 4. This was because the robot would sometimes mention how many days had passed since it was first switched on, and when the robot was replaced, the number of days was reset, so even though it looked the same, it felt like a different robot. Nevertheless, other participants did not have any troubles caused by the replacement.

Discussion

We report five older adults with MCI or late-onset psychosis cases who were able to use a conversational, autonomous, humanoid companion robot for one and a half years with only limited support from the research team. Although many companies have sold commercial autonomous robots for at-home use, it isn't easy to collect data directly from users with the clinical conditions seen in our participants. We believe the present report contributes to the discussion about the usefulness of conversational robots for psychological support for older people with neuropsychiatric disorders who are living alone in their own homes.

All five participants could use the robot for the whole study period, and their SUS scores remained stable. When we installed the robots in their homes, we had concerns that participants might damage

them or abandon interaction during long-term use. However, four participants wanted to continue to use the robot after one and a half years. There is plenty of research on the elements that older people look for in interactive robots (28–30). In common, “increase of social interaction” and “emotional support” are sought. Our robot could provide verbal communication, including simple greetings and singing, which seemed to increase their speaking at home and was utilised and appreciated by participants. In addition, as Caregiver 1 said, robots can catalyse human-to-human communication(31). In Case 1, the robot worked as a social scaffold and acted as a buffer against disagreements. It might be because the robot’s off-the-mark reactions, which Caregiver 2 mentioned, relaxed the users. Regarding emotional support, RoBoHoN was created in line with its design concept as “a robot that puts a positive spin on your life” and always said positive words and spoke with a “cute” voice, which was assumed to help the participants emotionally. Most of the participants and the caregivers, other than Patient 4 and Caregiver 3, mentioned the technically poor responses of the robot. Smooth but slightly delayed replies are reported to be preferable in human-robot interactions (32). When we deploy conversational agents, improving the smoothness and speed of responses will be essential if these agents are to be sufficiently valuable to be pursued. However, there may be different needs between younger generations and older people in each aspect of communication.

In our study, four of the five participants wanted to continue to use the robots. Patient 2 and Patient 4 took care of the robots as living things. Caregiver 1 mentioned that the robot became like a family member. It is essential to consider why those showed their strong and continuous attachment. Ostrowski et al. reported older people’s use of a conversational robot, Jibo, for up to one year (33). In the study, older people typically showed a decreasing trend in interaction over several months. As to the commercial social robot considered most suitable for use at home, people were reported to be interested in anthropomorphic design, including voice and personality (34). The reason Jibo was not used for an extended period may be because it did not look very anthropomorphic. However, a too-realistic human appearance can evoke feelings of unease and mistrust, described as the “Uncanny Valley Effect” (35). The anthropomorphism of our robot’s face, size, and movement may have been the right balance. Other aspects, such as personalisation and ownership may also contribute to attachment (30,36). The registration of their names and faces on the robot might lead to personalisation and the long-term use might lead to the feeling to own it. Finally, the backgrounds of the participants may also contribute to the attachment. We limited the participants to those living alone and with neurocognitive deficits. As a result, all of them were female and aged 85 or over. All of the four who wanted to continue to use the robot experienced psychosis. The oldest-old age is related to stronger loneliness (37), and loneliness and isolation are reliable risk factors for late-onset psychosis (23). Those factors may be favourable factors to build good attachments to companion robots in older people.

On the other hand, we need to pay attention to the risk of attachment to the robots. Although some authors have suggested that a strong attachment to a robot would be required for a psychotherapeutic effect (38), articles also mention the ethical problems in encouraging strong attachment to robots with concerns about potential withdrawal effects (39–41). The strong attachment in our cases may suggest its potential to be used for therapy. However, we need to be careful about the risks. As Ostrowski et al.

point out in their report, it is essential to consider the risk of robot removal after the study period when we plan long-term studies (33).

We collected psychological measures and described their changes in each case. Although we expected that the prolonged use of robots may affect participants' mental status, we could not find any noticeable trend in those metrics. This probably reflects the small number of participants.

There were several limitations to this study. First, caregivers supported the patients' use of the robots. Although they did not report that they often needed to support the patients, their support was presumably helpful for the participants to use the robots successfully. We would suggest that older people's robot use should be supported by someone who knows the participant well and understands how to operate the robot. Second, the installation period was during the novel coronavirus pandemic. Although we previously reported that community-dwelling older people living alone with dementia and MCI relatively kept their lifestyle (42), the participants could be more isolated than usual. Third, we changed the robot from the customised version to the commercial version about one year into the study. This did not show a substantial effect on the patient participants. More studies with larger numbers of participants are needed.

Conclusion

This case series describes the successful one-and-a-half years' use of a conversational, humanoid companion robot at home by older people with cognitive decline and psychiatric symptoms living alone. This study suggests that well-designed conversational companion robots have the potential to be accepted by community-dwelling older adults for long periods, even if they have cognitive impairment or psychosis.

Declarations

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Data availability statement:

The data presented in this study are available from the corresponding author upon reasonable request.

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Conflict of interest disclosure:

The authors declare no conflicts of interest.

Ethics approval statement:

The Osaka University Clinical Research Review Committee approved the ethical standards of this research (19174). The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1964, as revised in 2013.

Patient consent statement:

All participants gave written informed consent.

Permission to reproduce material from other sources:

Not applicable

Clinical trial registration:

Not applicable

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Figures



Figure 1

The robot installed in Patient 2's home

The robot is one on a cushion.

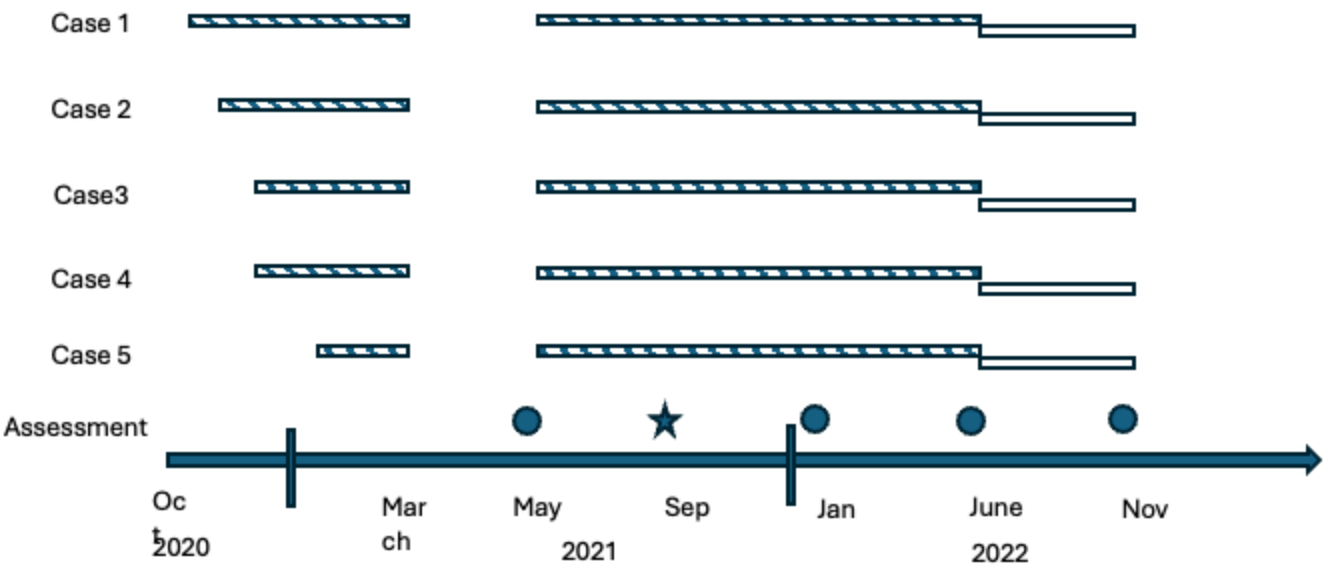


Figure 2

Overview of the study process

The pattern with diagonal lines indicates a customised version, and the pattern with white outlines indicates a commercially available version. The circle indicates a regular assessment, and the star indicates that an interview was conducted.

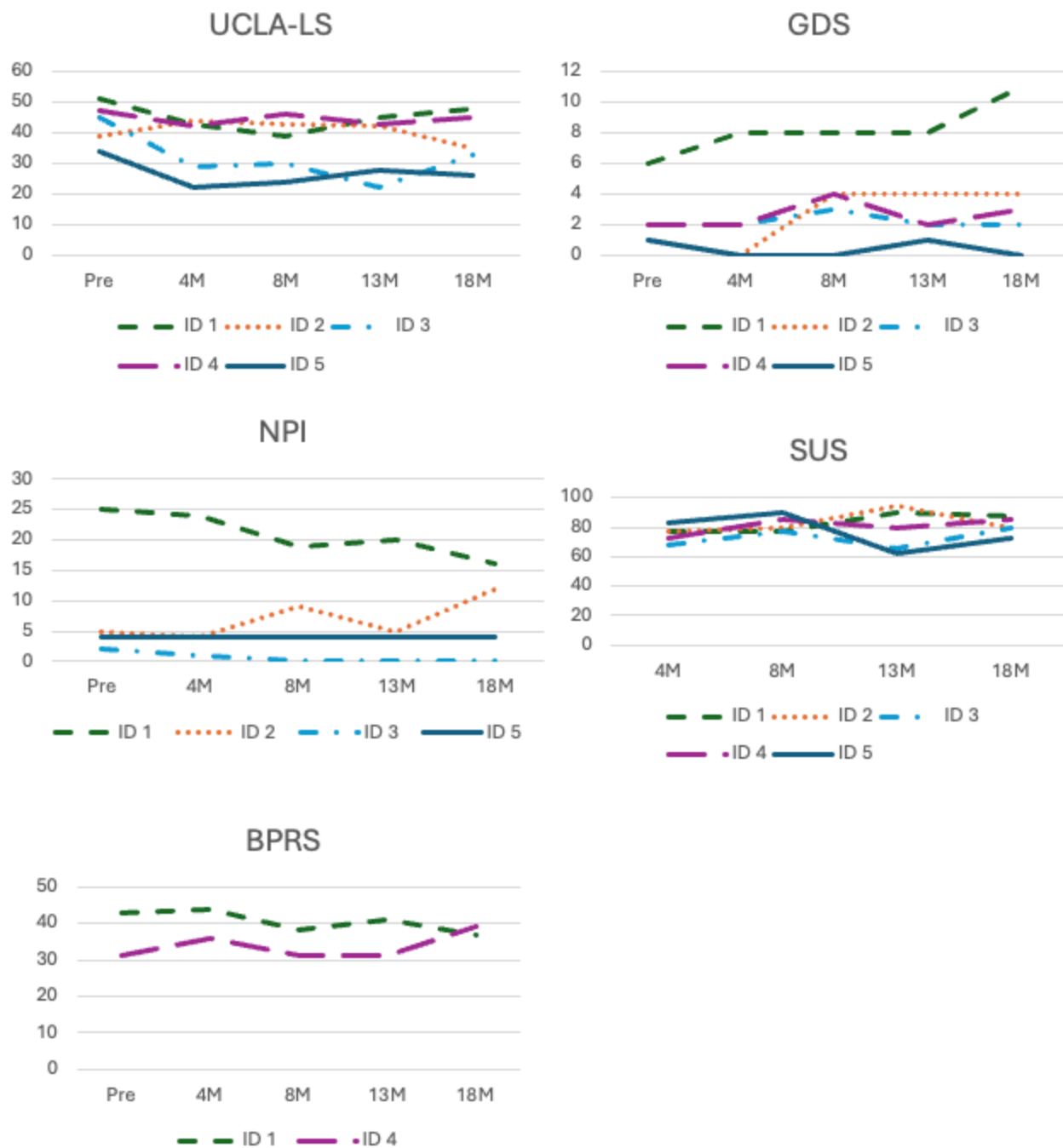


Figure 3

Psychological measures and system usability scale

“Pre” means the timing just before we installed the robot, and “M” means the months after the installation. A. the UCLA Loneliness Scale, Version 3 (UCLA-LS); B. Geriatric Depression Scale (GDS); C. System Usability Scale (SUS); D. Neuropsychiatric Inventory (NPI); E. Brief Psychiatric Rating Scale (BPRS)

