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RESEARCH

Longitudinal changes following the introduction of socially assistive robots in nursing homes: a qualitative study with ICF framework and causal loop diagramming

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Abstract

Background Socially assistive robots introduced in nursing care settings have multidimensional psychological impacts on care recipients and caregivers. This study aims to explore the longitudinal changes induced by socially assistive robots, focusing on a chain of human behaviors.

Methods In this qualitative study, nine participants from two nursing homes who had experience in manipulating socially assistive robots were interviewed in a semi-structured focus group using a topic guide to explore the changes in care recipients and caregivers. Following the framework analysis method, the transcripts were coded using the International Classification of Functioning, Disability, and Health (ICF). The identified codes were charted for each side—care recipients and caregivers sides— using a causal loop diagram, a tool used to visualize nonlinear dynamics in complex systems.

Results Three and seven kinds of codes in the domains of "body functions" and "activities and participation", respectively, were identified on the care recipients' side; whereas on the caregivers' side, one and five kinds of codes in the domains of "body functions" and "activities and participation", respectively, were found. The codes obtained from the facility with longer experience were represented graphically as a reinforcing feedback loop, in which favorable changes were amplified in a chain of events. Robot use directly changed the mental functions of care recipients, and the caregivers' perceptions of these positive changes led to their own emotional and behavioral changes, which would reduce the burden of care. Moreover, the findings suggest that sharing information regarding these changes and objectively recognizing the effectiveness of robots among staff members can be the key to continuous robot use in nursing care settings. Conversely, the figure obtained from the novice facility shows fragmented chain relationships of the codes, indicating that all the effects of robot use are recognizable and form a chain reaction after continuous robot use for more than several months.

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Conclusions This study revealed important aspects regarding the longitudinal effects of socially assistive robots in nursing care settings. These implications should be broadly implemented for effective robot use and reduction of the burden of care in nursing care settings.

Clinical trial number Not applicable.

Keywords Assistive robotics, Long-term care, ICF, Care recipients, Caregivers, Mental functions, Staff communication, Burden of care

Background

Recent worldwide trends of declining birthrates and aging populations have resulted in a shortage of caregivers in clinical scenes [1, 2]. Against this background, the implementation of assistive robots and devices in nursing care has been encouraged to maintain quality of care [3]. However, the widespread use of these technologies has not been fully realized; one reason is that it takes time to develop proficiency in using new technologies. A previous study has revealed that a clear progression is observed over time in the ability to engage with new technologies in nursing care settings [4], suggesting that the effectiveness could become apparent after continuous use of the devices. Conversely, in the early stages of the introduction of a new robotic device, drawbacks, such as difficulty or complexity of operation, may exceed the benefits of reducing the burden of caregiving. When the expected benefits are not achieved, the frequency of using the device decreases to the extent that its true value is not realized. To prevent these undesirable results, focusing on the positive aspects of the changes in the earlier stages is considered important. This would encourage further robot use and promote a positive chain reaction for sustainably developing its effects. Among the various types of assistive robots and devices, socially assistive robots, which are designed to support the caregiving process through communication and social interaction with the user [5, 6], have a particularly varied psychological impacts on the humans they interact with [7]. Therefore, it is especially useful to organize various human reactions induced by socially assistive robots in a manner that highlights their effectiveness and encourages enough continuous use to obtain their true value. Nevertheless, to the best of our knowledge, no study has explored the longitudinal changes induced by socially assistive robots, focusing on the chain of human behavior.

The International Classification of Functioning, Disability, and Health (ICF) [8], proposed by the World Health Organization (WHO), is not only well established in the field of health and welfare, but has also drawn attention from the field of engineering as a tool for capturing and describing the impact of welfare engineering on human life [9, 10]. The ICF describes human functioning as the interaction of body functions, activities, and participation and provides a taxonomy that includes components and second-order codes [11]. Previous qualitative studies on people with disabilities and those requiring care [12–16] have found that the ICF framework can be successfully used to sufficiently address a subject's expressions or daily life. Therefore, capturing the impact of socially assistive robots using the ICF, which provides a comprehensive and multidimensional representation of human life, is beneficial for accurately understanding chain reactions or the complexity of introducing robotics in nursing care settings.

Therefore, this study aims to clarify the longitudinal changes initiated by introducing socially assistive robots in nursing care facilities by adapting the ICF framework for humans involved, that is, care recipients and caregivers. Furthermore, we aim to elucidate the continuity and causal relationships in multiple phenomena following the introduction of robots.

Methods

Design

This qualitative study used focus group interviews, a method that encourages several participants to talk and interact with each other, in addition to answering the facilitator's questions individually [17]. Its application has grown across a wide range of disciplines including health research [18] and its methodology has been established [19]. This interview method promotes recall of relevant events inspired by the statements given by other participants, compared to individual interviews [20]. This style was adopted because it is suitable for clarifying these chains of events and their causal relationships, which is the purpose of this study. Furthermore, the method of semi-structured interview method, which uses open-ended questions that define the area to be explored to encourage the interviewees' own narrative [21], was adopted in asking questions to interviewees (see the topic guide below in "Data Collection").

Ethical consideration

The study protocol conformed to the Declaration of Helsinki and was approved by the ethics committee of the Kanagawa Institute of Industrial Science and Technology (approval date: February 7, 2022) and the ethics committee of the National Center for Geriatrics and Gerontology (No. 22TB20). This study was conducted according to the consolidated criteria for reporting qualitative research [22]. All the study participants provided written informed consent prior to participating in the study.

Study setting

Interviews were conducted at two nursing care facilities in and around Tokyo, Japan, where PALRO (Fuji Soft Incorporated, Kanagawa, Japan), a socially assistive robot, had been implemented at the time of recruitment. PALRO is a humanoid-type robot that is small enough to be portable, 40 cm in height and 1.8 kg in weight, and it is capable of daily conversation through its voice recognition function. It also provides songs, dances, exercises, and quizzes while moving its arms and legs using its actuators (Fig. 1). The two facilities interviewed (facilities A and B) had been using PALRO routinely in clinical settings. Specifically, facility A has deployed PALRO for approximately five years. It was used regularly during group recreation activities, pre-mealtime exercises for swallowing function, and interacting with individual residents during their free time. Facility B had introduced PALRO around three months prior to the study interview. After the staff had familiarized themselves with its operation in the staff room, it was deployed routinely for group recreation and occasionally for interacting with individual residents.

For the participants' convenience and to prevent COVID-19 transmission, we conducted the interviews with these facilities via web conferences [23].

Participants

Participants were recruited from the staff of two nursing care facilities between February 2022 and April 2022. The inclusion criteria were as follows: (1) experience in manipulating PALRO and (2) a professional engaged in the field of nursing care and welfare, such as a nurse, a caregiver, or a care clerical worker. Eventually, the participants were determined to reflect the occupational diversity within the facility based on the concept of theoretical sampling [20]. Care recipients in the target facilities were not recruited in this study, given that they typically have cognitive decline and find it difficult to explain past events in sequence.

Data collection

Semi-structured interviews were conducted in which interviewers asked open-ended questions relevant to the research topic between March 2022 and February 2023 (two days at facility A and one day at facility B). Two interviewers (EO, a rehabilitation physician with 12 years of work experience, and KS, a physical therapist with 16 years of work experience) had no personal relationships with the interviewees. The topic guide was as follows: (1) What changes occurred in care recipients and caregivers when PALRO was first applied, and (2) How have the care recipients and caregivers reacted to the issues accompanied by using PALRO for a long period? The guide was pretested and determined prior to the interview through discussions among the aforementioned interviewers (EO and KS) and a medical doctor (IK, with more than 30 years of clinical experience) to detect changes over time. Additionally, after the participants responded to the topic question, the interviewers prompted them to refer to the subsequent changes following the event. The interviews were audio-recorded with the participants' permission.

Analyses

All transcripts were anonymized and analyzed using framework analysis [24]. In framework analysis, a list of codes is determined in advance of the analysis and then applied to the transcripts, producing highly structured outputs of the summarized data [25, 26]. This method is considered suitable if the concept to be fitted exists in advance [12, 27]. According to the purpose of the present study, the transcripts were coded using the conceptual framework provided by the ICF. The ICF categories are arranged in a stem-branch-leaf structure, that is every domain consists of chapters, which include several second-level categories. An ICF code is a combination of a letter representing a domain ("b" for body functions and "d" for activities and participation) and numbers representing the chapter and second-level categories. As an example, the body functions domain includes Chap. 1: Mental Functions, Chap. 2: Sensory Functions and Pain, Chap. 3: Voice and Speech Functions, and more. The categories defined in Chap. 1 include "b110. consciousness functions," "b114. orientation functions," "b117. intellectual functions," "b134. sleep functions," and so forth [11]. Regarding activities and participation, the WHO guideline states that it is difficult to make a uniform distinction between "activity" and "participation" because the same category can describe both the individual issue (actions performed by the individual) and social issue (involvement in life and life situations) and that users should make their own judgment based on the purpose of use. Therefore, no clear judgment was made regarding the domains of activity and participation in this study, and a second level of explanation was used as the code to be assigned. For example, statements regarding the nursing home staff using the robot for residents' care were coded as "d210. undertaking a single task" on the caregivers' side, and statements regarding residents' responses following the use of the robot were coded as corresponding categories in the ICF on the care recipients' side. First in the coding process, one author (EO) identified the semantic units of the sentences throughout the transcript and applied an ICF code to each unit by referring to the WHO definition [11]. Another author (KS) subsequently

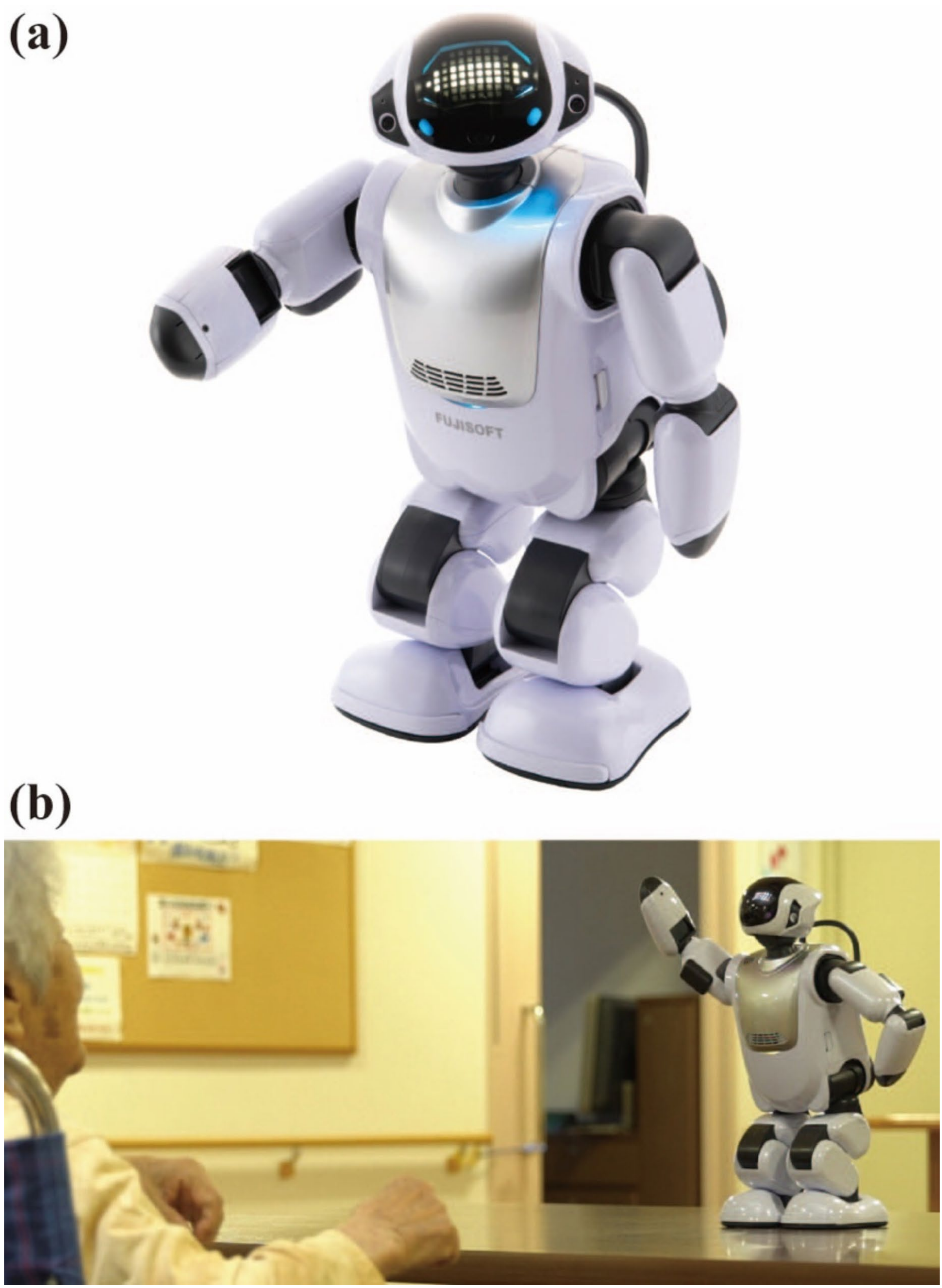

Fig. 1 PALRO, a socially assistive robot. (**a**) The whole appearance of PALRO. (**b**) PALRO conversing with a nursing home resident

confirmed the coded transcript and listed inconsistencies regarding the identification of the units and application of codes. Disagreement was discussed until a consensus was reached, and the remaining uncertainties were resolved by discussing with the other researchers (DS, YN, YM). Subsequently, paragraphs with the ICF codes were extracted and substantial relationships between these codes were identified based on the context of the transcript. Finally, the ICF codes were charted on each of the care recipients' and caregivers' sides using a causal loop diagram, a qualitative tool used in systems thinking [28] to visualize nonlinear dynamics in complex systems that characterize health issues [29]. This method has been previously adopted to address problems and realities in healthcare [30–33]. A causal loop diagram was created for each facility to understand the phenomena that occurred in each community and their causal relationships separately. MAXQDA Analytics Pro 22.2.0 (Verbi Software, Germany) was used for coding and drawing the outline of the causal loop diagrams.

Results

Nine participants from two nursing homes were interviewed. Details of the participants are listed in Table 1. The focus group interviews lasted 90 min at facility A (60 min on day 1 and 30 min on day 2) and 45 min at facility B.

In total, 76 ICF codes, 7 chapters, and 12 categories were derived from the interviews. The data obtained from facility A included 57 codes, 7 chapters, and 10 categories, while the data from facility B included 19 codes, 5 chapters, and 8 categories. Three and seven kinds of codes regarding the domains of "body functions" and "activities and participation," respectively, were identified on the care recipients' side. On the caregivers' side, only one kind of code regarding the domains of "body functions" and five regarding "activities and participation" were identified. The ICF framework domains, chapters, and codes identified in this study are summarized in Table 2.

Table 1 Participants' demographic characteristics

Facility	Participant number	Gender	Years on the job	Occupation
A	1	M	18	Chief Caregiver
	2	F	14	Caregiver Leader
	3	F	11	Caregiver
	4	M	11	Manager
	5	F	23	Chairman
B	1	F	8	Nurse
	2	F	14	Care Manager
	3	M	10	Caregiver
	4	M	17	Chairman

The causal relationships of the codes clarified in the data from facility A mainly demonstrated a large reinforcing feedback loop in which favorable changes were amplified in a chain of events (Fig. 2). Three main loops had some common parts that included a small loop describing the reinforcing relationship between the caregivers' "d720. complex interpersonal interactions" (communicating among staff) and "d210. undertaking a single task" (using PALRO for care recipients). For example, the participants mentioned the relationship between robot use and staff communication as follows: "All of the nursing staff frequently told us [the managers] about the good things they had experienced [by using the robot] with a twinkle in their eyes. They told us many good things, such as detailed changes in the care recipients and their reactions; so, I feel that the distance between us was greatly shortened by the introduction of the robot." (Participant No. 5, Facility A).

"I would give them [other staff] advice like, 'you could use PALRO at these points, and then you can make time, so you might as well do this in the meantime.' In this way, the number [of staff members who could make good use of PALRO] gradually increased." (Participant No. 1, Facility A).

Importantly, all arrows from the care recipients' side toward the caregivers' side originated from the codes of mental functions in the body functions domain ("b140. attention functions" (focusing on PALRO), "b147. psychomotor functions" (staying calm), and "b152. emotional functions" (being happy and engaged)). Above all, "b147. psychomotor functions" (staying calm) of the care recipients were observed to induce emotional changes in the caregivers, as one participant described that staff members feel happy and lucky that the robot works when they see the residents who normally cannot sit for 5 min calmly sitting for 10 min (Participant No. 1, Facility A). Additionally, "b140. attention functions" in care recipients was connected to the caregivers' "d220. undertaking multiple tasks" (dealing with multiple residents). One participant said, "When a person with dementia is doing something, the staff's hands are occupied with that. With this PALRO, the other residents can concentrate on PALRO, and we can take care of another person [with dementia] without worry." (Participant No. 4, Facility A).

Further, the only small balancing feedback loop, which tends to suppress changes in a chain of events, was found between "d210. undertaking a single task" (using PALRO for care recipients) of the caregivers and "d330. Speaking" (refusing PALRO) from the following phrase: "some of the people to whom we wanted to try to use it [the robot] by putting it on the table individually expressed their intention properly that they did not like it, so for those people, we basically do not use it anymore." (Participant No. 2, Facility A).

Table 2 ICF codes and example quotations

(a) body functions domain

Chapter -subcategory	ICF Code		General Description by WHO	Specific theme in this study	Examples quotations
Mental functions -specific mental functions	b140	attention functions	Specific mental functions of focusing on an external stimulus or internal experience for the required period of time	< care recipients' side> Focusing on PALRO	The residents who I thought would not be able to concentrate actually [concentrated and] chatted for much longer when talked to [PALRO]. (P4, A)
	b147	psycho-motor functions	Specific mental functions of control over both motor and psychological events at the body level	< care recipients' side> Staying calm	The residents who tend to be restless and stand up often are somewhat calmer when PALRO is around. (P5, A)
	b152	Emotional functions	Specific mental functions related to the feeling and affective components of the processes of the mind	< care recipients' side> Being happy and engaged < caregivers' side> Feeling happy and lucky	Everyone is delighted when they see [PALRO] dance and sing. (P2, B) It [PALRO] remembers your birthday and look for you in the morning. It makes me a bit kind of happy, or familiar. (P3, B)

(b) Activities and participation domain

Chapter -subcategory	ICF Code		General Description by WHO	Specific theme in this study	Examples quotations
Learning and applying knowledge -basic learning	d155	Acquiring skills	Developing basic and complex competencies in integrated sets of actions or tasks so as to initiate and follow through with the acquisition of a skill, such as manipulating tools or toys or playing games	< care recipients' side> < caregivers' side> Learning the exercises	When we do this [have PALRO do exercises for better swallowing before lunchtime], amazingly the residents become so habituated to it that they generally remember it and do it without looking [at the robot]. (P5, A)
General tasks and demands	d210	Undertaking a single task	Carrying out simple or complex and coordinated actions related to the mental and physical components of a single task, such as initiating a task, organizing time, space and materials for a task, pacing task performance, and carrying out, completing, and sustaining a task	< care recipients' side> Doing the exercises	Everyone does the exercise following PALRO. (P4, A)
	d220	Undertaking multiple tasks	Carrying out simple or complex and coordinated actions as components of multiple, integrated and complex tasks in sequence or simultaneously	< caregivers' side> Dealing with multiple residents	While PALRO was talking to that person, for example, I would watch over or direct another person to the toilet, and so on. (P1, A)
Communication -communicating-producing	d330	Speaking	Producing words, phrases and longer passages in spoken messages with literal and implied meaning, such as expressing a fact or telling a story in oral language	< care recipients' side> Talking to PALRO	I saw them trying to tell PALRO their names properly and talking to PALRO like, 'How are you?" (P1, A)
Communication -conversation and use of communication devices and techniques	d350	Conversation	Starting, sustaining and ending an interchange of thoughts and ideas, carried out by means of spoken, written, signed or other forms of language, with one or more people one knows or who are strangers, in formal or casual settings	< care recipients' side> < caregivers' side> Talking about PALRO with others	We can talk about PALRO as a conversation, we can do it with the residents, we can do it between staff, and I think that is the biggest thing. (P4, B)
Mobility -changing and maintaining body position	d410	Changing basic body position	Getting into and out of a body position and moving from one location to another, such as getting up out of a chair to lie down on a bed, and getting into and out of positions of sitting, standing, kneeling or squatting	< care recipients' side> Raising the hips from a seated position	It's not such dangerous, but it still makes [the resident] stand up a bit. (P2, B)
Mobility -walking and moving	d460	Moving around in different locations	Walking and moving around in various places and situations, such as walking between rooms in a house, within a building, or down the street of a town	< caregivers' side> Coming up around PALRO	It's like when one person does it [talk to PALRO], they all come up [to PALRO] in a wow. (P4, A)

Table 2 (continued)

(b) Activities and participation domain

Chapter -subcategory	ICF Code		General Description by WHO	Specific theme in this study	Examples quotations
Interpersonal interactions and relationships –general interpersonal interactions	d720	Complex interpersonal interactions	Maintaining and managing interactions with other people, in a contextually and socially appropriate manner, such as by regulating emotions and impulses, controlling verbal and physical aggression, acting independently in social interactions, and acting in accordance with social rules and conventions, when for example playing, studying or working with others	< caregivers' side> Communicating among staff	I think it is a change for the staff where we, the management, can always communicate with the staff who uses it [PALRO] more frequently. (P1, A)
Community, social and civic life	d920	Recreation and leisure	Engaging in any form of play, recreational or leisure pursuit, such as informal or organized play and sports, programmes of physical fitness, relaxation, amusement or diversion, going to art galleries, museums, cinemas or theatres; engaging in crafts or hobbies, reading or singing for enjoyment, playing musical instruments; sightseeing, tourism and travelling for pleasure	< care recipients' side> Applauding performance in a recreation time	At the recreation time, [PALRO's] arms and legs move a lot, so [the residents] clap and cheer saying it's amazing or applaud the movements. (P3, B)

Conversely, the data obtained from facility B showed a small loop related to conversation and fragmented chain relationships starting from "d210. undertaking a single task" (using PALRO to the care recipients) on the caregivers' side; however, no reinforcing feedback loops comprising three or more codes were found. The ICF codes included in the fragmented chain in facility B were partly mutual with the codes derived from facility A ("b140. attention functions" (focusing on PALRO), "b147. psychomotor functions" (staying calm), "b152. emotional functions" (being happy and engaged) in body functions domain, and an arrow from "d330. Speaking" (talking to PALRO) to code b152). A simple reinforcing feedback loop regarding "d350. conversation" (talking with residents/caregivers about PALRO) did not show the relationship with "d210. undertaking a single task" (using PALRO for care recipients), or other codes (Fig. 3).

Discussion

This study explored the changes that have occurred with the introduction of socially assistive robots in nursing care facilities through qualitative analysis using the ICF framework for care recipients and caregivers. In summary, using socially assistive robots induced various reactions at each level of the ICF domain (body functions, activities, and participation) on both the care recipients' and caregivers' sides. Compared to the novice facility, the notable characteristic of the facility with longer experience was that the changes in care recipients' mental functions (coded in the body functions domain) led to changes in caregivers' activities and participation, resulting in the formation of feedback causal loops that encouraged robot use.

This study is the first to visualize a series of changes induced by robots in a realistic manner, that is, with multidimensionality and complexity. In particular, the use of the ICF in diagramming was effective in detecting causal relationships among human reactions induced by the introduction of robots. Regarding assistive robots and the ICF, several studies have previously adopted the ICF to characterize the physical or cognitive conditions or personal requirements of robot users [9, 10, 34]. However, this study is characteristic in that the ICF was adopted to describe the impact on robot users, whereas most previous studies adopted the ICF in the process of developing robot functions. Notably, the categories of ICF codes detected in this study ranged from mental function to multiple aspects of activities and participation, such as communication, mobility, learning, and interaction. These findings suggest that interactions with socially assistive robots affect diverse aspects of daily life. Obayashi et al. [35] described the effects of robots on older persons using the ICF; however, the codes used were the pre-selected part of the activities domain, and some of the codes did not detect actual changes. In this regard, this study applied ICF codes corresponding to the identified data and identified codes that reliably reflected actual changes. Moreover, this study successfully elucidates the continuity and relationships among multiple ICF codes by clarifying the temporal sequence of events and not merely examining the presence or absence of change.

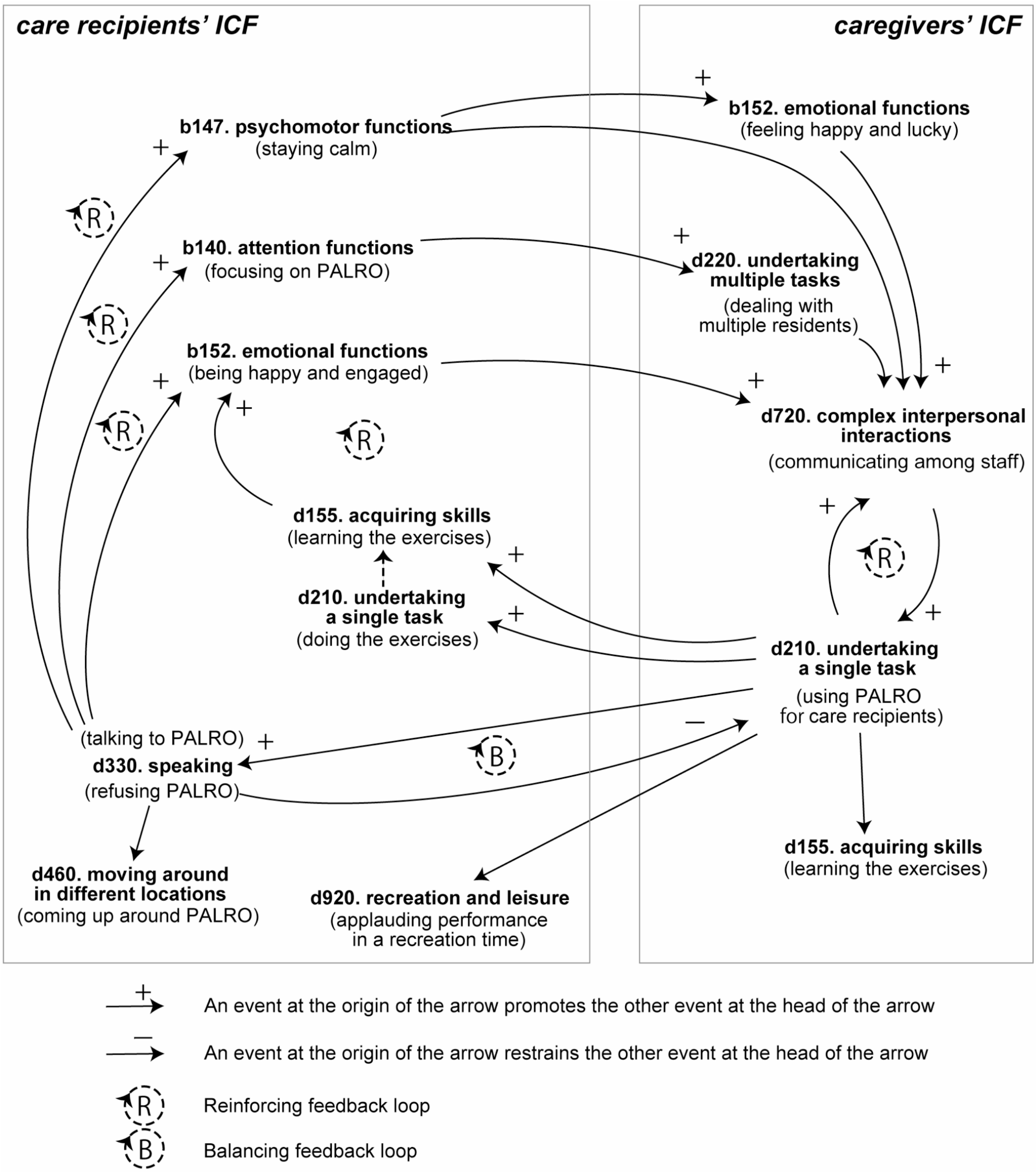

Fig. 2 Causal loop diagram depicted from the interview transcript of facility A (the facility with longer experience)

Another strength of this study is that it revealed the psychological and behavioral changes in caregivers following the introduction of socially assistive robots. While socially assistive robots are known to have relatively positive emotional effects on older people [36, 37] and people with dementia [38, 39], their effects on caregivers had not previously been fully investigated. This study reveals that the changes in care recipients' mental function led to a chain of behavioral changes in caregivers in the nursing home with long experience using socially assistive robots. This suggests that caregivers' perceptions of positive changes in the mental aspects of care recipients may

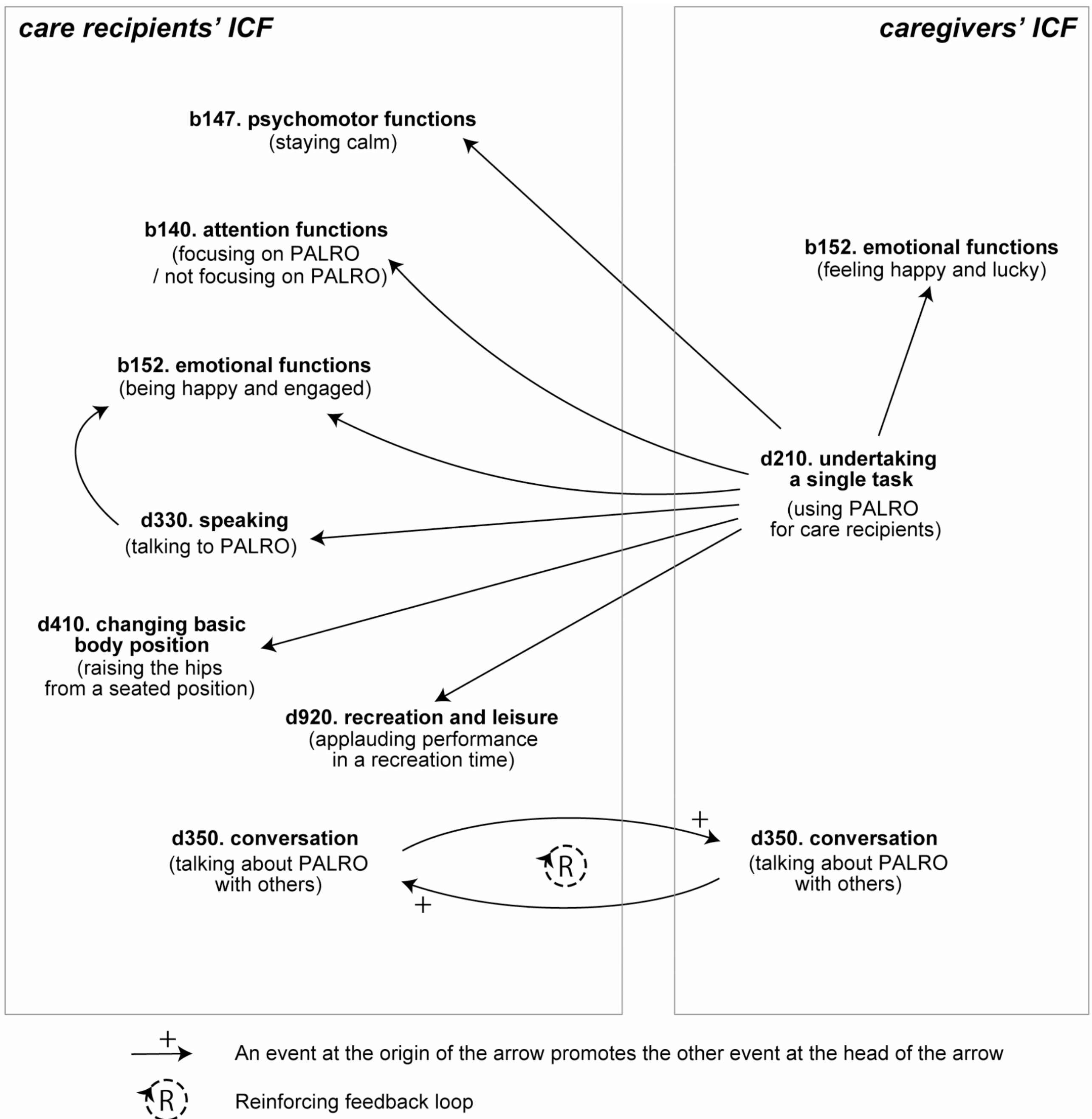

Fig. 3 Causal loop diagram depicted from the interview transcript of facility B (the novice facility)

have brought about positive responses in the caregivers themselves in terms of care performance or their own emotions. More interestingly, the caregivers' perception of increased attention toward robots in care recipients was shown to allow them to perform multiple caregiving tasks. As these changes in caregivers potentially reduce the burden of caregiving work, the findings are considered part of the effectiveness of socially assistive robots. These sequential changes should be broadly acknowledged and implemented to reduce the care burden. Furthermore, a reinforcing feedback loop regarding robot use and communication among the nursing care staff was found. This can be interpreted as sharing information regarding robot use and the induced changes resulted in staff members objectively recognizing the effectiveness of the robot, contributing to its further use across the workplace. This interpersonal interaction among nursing care staff is considered the key to highlighting the effectiveness of socially assistive robots and encouraging continuous robot use in nursing care settings.

A comparison of the results from the novice facility with those from the facility with longer experience revealed that some of the codes and their relationships on the care recipients' side were common, although they did not form a loop. Specifically, whereas the changes of mental functions on the care recipients' side emerged in both facilities, the relationship between these changes and caregivers' behavioral changes was not identified in the novice facility. These differences may be attributed to the duration of robot use. That is, some of the changes in care recipients could become evident in the first several months. In contrast, transition of the impact from care recipients toward caregivers may take time to be developed. More continuous use, perhaps on a yearly basis, might be necessary before a chain reaction is formed and all the effects of robot use are recognizable. Given these findings, supportive interventions, such as providing opportunities for nursing care staff to discuss the changes in care recipients observed in relation to robot use and making them aware of its effectiveness, may be useful in promoting the continuous use of robots.

This study has several limitations. First, it included nursing homes that successfully and continuously used robots. There may be different (possibly negative) changes or linkages in facilities with different experiences, such as the abandonment of robot use. Second, as the interviews encouraged participants to recount events on a yearly basis, recall bias could have influenced the lack of information on certain (possibly negative) events. Third, this study examined two different facilities; however, the development of the effects over time should be strictly assessed within the same facility over different time points. To overcome these issues, further studies that prospectively examine robot introduction and sequential changes over time across multiple facilities are necessary. Next, this study investigated facility-wide changes as a whole; therefore, the characteristics of care recipients were not considered in the interviews or analysis. However, when focusing on individual experiences of robot use, the reactions elicited in the care recipients can vary depending on their physical conditions or cognitive functions. Future studies with a design that includes care recipients' information are needed to specifically determine what kind of direct reactions occur for each care recipient. Furthermore, the relatively small sample size may somewhat limit the generalizability of these results. Finally, the study data were collected only from caregivers and not from care recipients in this study, as mentioned in the section on participant selection. A different study design, other than interviews, would possibly allow the integration of the data obtained from the care recipients themselves reflecting the longitudinal changes. Despite the above limitations, we believe that this study reveals important aspects regarding the longitudinal effects of socially assistive robots in nursing care settings to help continuous robot use and improve care recipients' daily lives.

Conclusions

In conclusion, this study qualitatively elucidated the longitudinal changes caused by socially assistive robots in both care recipients and caregivers through the ICF framework and causal loop diagram, helping to understand the complexity of introducing robotics in nursing care settings. Robot use was revealed to cause changes in mental functions in care recipients, and caregivers' perceptions of these positive changes were found to bring about their own emotional and behavioral changes. Moreover, the findings suggest that sharing information regarding these changes and objectively recognizing the effectiveness of robots among staff members can serve as the key to continuous robot use in nursing care settings. These implications should be broadly implemented for effective robot use and to reduce the burden of care in nursing care settings.

Abbreviations

ICF	The International Classification of Functioning, Disability, and Health
WHO	The World Health Organization

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Author contributions

EO, YN, and YM conceptualized and designed the study. TY participated in determining the study design and methodology. EO and KS collected and analyzed data. TN and NS participated in participant recruitment and data collection. EO drafted the manuscript. KS, DS, and TY interpreted the data and edited the manuscript. TN, NS, YN, YM, and IK participated in data interpretation and critical revision of the manuscript. All authors have read and approved the final manuscript.

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Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to privacy and ethical restrictions but are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Ethics Committees of the Kanagawa Prefectural Institute of Industrial Science and Technology and the Ethics Committee of the National Center for Geriatrics and Gerontology (approval number 22TB20). All participants provided written informed consent before participation.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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