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Robots for Better Communication: A Minimal-design Approach and Theory of Active Co-presence

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Robots for Better Communication: A Minimal-design Approach and Theory of Active Co-presence

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Abstract

The overall motivation of this study is to have a better communication by using telecommunication media. The focus of the study is to make a positive impression of the speaker to promote the interactive eagerness of the user. This thesis hypothesized that positive impression can be fostered by "less information" and "physical embodiment". Mediated communication lack some information compared to face-to-face communication. Therefore, users imagine and complete the lack of information, e.g. facial expression. By hugging the medium during the interaction, users might think of the conversation partner as in a good relationship and foster positive impression. A minimal-design robot, a robot which has minimal modality to feel a human presence, is used as the communication medium to test the hypothesis. It has a neutral appearance and transfers minimal information of the speaker, and the user can physically interact with it.

This thesis focuses on communication support of seniors with dementia. Seniors with dementia have low sensing and cognitive function due to their age, and they can receive a limited amount of information. They often complete the lack of information in their mind in order to communicate with others. For example, they often complete the words from the context when they missed hearing. Since the information they can perceive is limited, they become sensitive to the information. Therefore, such minimal-design robot which fosters users to imagine positively would be effective.

The users imagine whom they are talking to when they interact with the speaker talking from the robot. By hugging the robot which would be hesitated in face-to-face communication, the partner would imagine the partner as in a good relationship. First, experiments were conducted to reveal the characteristic of the minimal-design appearance and the effect of the hug. Then, fieldworks at elderly care facilities were conducted to revealed how the robot affects seniors with dementia and whether it can foster positive impression to promote conversation. From the result, *Theory of Active Co-Presence*, a new method to enhance co-presence of remote person, is discussed.

In the first experiment, the appearances of three communication media (minimal-design robot, nonhuman-like robot, and video chat with a projection of the speaker) are compared. The result shows that, in the case of the minimal-design robot, the consistency of personality judgment is better than in the case of the nonhuman-like robot. Also, teleoperated robots transmitted a more appropriate atmosphere due to the context, although the video chat transmitted more nonverbal information, such as facial expressions. In the next experiment, the result shows that users foster to imagine and have a positive impression of the speaker by

hugging the communication medium. From the results, the mechanism of how the minimal-design robot enhances positive impression is discussed.

Then, fieldworks using the minimal-design robot in elderly care facilities are introduced. Teleoperated robot *Telenoid* is used to support communication for seniors with dementia in care facilities. Telenoid is the minimal-design robot covered with soft vinyl that can transmit a remote operator's voice and limited head movements. The conversation partner can physically interact (hug and touch) with the robot to feel the presence of the operator. The result from fieldwork in the facilities shows that seniors quickly become a fond of interaction with Telenoid, and seniors with dementia also like it. Also, the result shows that seniors with dementia are completing the lack of information positively to Telenoid. From the result, *Theory of Active Co-Presence*, a theoretical perspective of imagining positive impression by actively behaving to the communication medium which lacks information, is discussed. The theory indicates that, instead of the enrich information, limited information encourages users to imagine and complete to have a positive impression and promote communication.

Table of Contents

Chapter 1

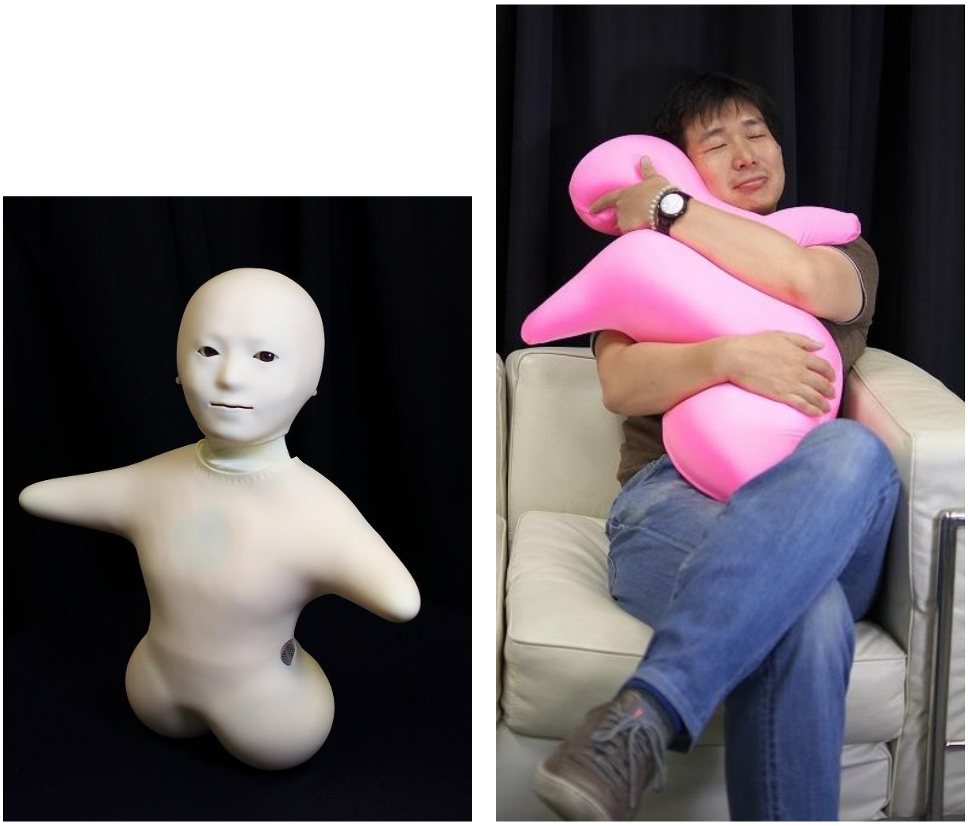
Introduction

Communication support is required for wider generations, especially to promote people to communicate. For example, the population of senior citizens is rapidly increasing worldwide, and seniors living alone are increasing. They become less active to establish a relationship, and less social connection increases a risk to become dementia [14, 24]. The number of elderly with dementia has reached 4.6 million, and an additional 4 million people probably suffer from mild cognitive impairment (MCI). Seniors with dementia sometimes become depressed and less motivated to talk due to the Behavioral and Psychological Symptoms of Dementia (BPSD). BPSD changes by time, and caregivers have to understand the current state of the seniors for the appropriate care. However, understanding the current state is difficult, especially when they are not willing to communicate.

The overall motivation of this thesis is to have a better communication by using telecommunication media. The focus of the study is to make a positive impression of the speaker to promote the interactive eagerness of the user. This thesis hypothesized that positive impression can be fostered by "less information" and "physical embodiment". Mediated communication lack some information compared to face-to-face communication. Therefore, users imagine and complete the lack of information, e.g. facial expression. By hugging the medium during the interaction, users might think of the conversation partner as in a good relationship and foster positive impression.

A minimal-design robot, a robot which has minimal modality to feel a human presence, is used as the communication medium to test the hypothesis (Figure 1.1). It has a neutral appearance and transfers minimal information of the speaker, and the user can physically interact with it.

Previous research of the teleoperated android (Figure 1.2) has shown that by interacting



(a) Telenoid (b) User using Hugvie

Fig. 1.1 Minimal designed communication media

via the android, the attitude and emotional state of people can be potentially influenced [66, 67, 118]. By mediating the android and communicate, the conversation partner's state might be influenced. However, the android is not designed to be used by anyone, since the appearance resembles a specific person. It costs about 10 million yen and needs a space for peripheral equipment, such as air compressor. Recently, minimal-design robot, a portable robot with a neutral appearance which has minimal modality to feel a human presence, is developed for anyone to use [93]. In this paper, how minimal-design robot affects people in communication is examined. Then, whether we can have a better communication by mediating the robot is discussed.

This thesis especially focuses on communication support of seniors with dementia. Seniors with dementia have low sensing and cognitive function due to their age, and they can

Fig. 1.2 Geminoid HI2 (right) and the model (left)

receive a limited amount of information. They often complete the lack of information in their mind in order to communicate with others. For example, they often complete the words from the context when they missed hearing. Since the information they can perceive is limited, they become sensitive to the information. Therefore, such minimal-design robot which fosters users to imagine positively would be effective.

The users imagine whom they are talking to when they interact with the speaker talking from the robot. By hugging the robot which would be hesitated in face-to-face communication, the partner would imagine the partner as in a good relationship. First, experiments were conducted to reveal the characteristic of the minimal-design appearance and the effect of the hug. Then, fieldworks at elderly care facilities were conducted to reveal how the robot affects seniors with dementia and whether it can foster positive impression to promote conversation. From the result, *Theory of Active Co-Presence*, a new method to enhance co-presence of remote person, is discussed.

Chapter 2 introduces related works and previous research of minimal-design robot. Chapter 3 introduces experiments which focus on the characteristics of the minimal-design robot and reveals the effect. By comparing minimal-design robot with existing communication media, the result shows that the minimal-design robot transfers speaker's personality consistently and appropriate atmosphere. Then, the other experimental result shows that users have positive impression of the speaker and strong feeling of being together with the speaker by hugging the medium to communicate. Based on these results, the mechanism of how the minimal-design robot influences the user is discussed.

Chapter 4 focuses on communication support of seniors with dementia as an application of the minimal-design robot. In previous works of a short-term experiment using minimal-design robot “Telenoid”, seniors with dementia favored interacting with Telenoid. In this thesis, a long-term fieldwork was conducted and revealed that seniors with dementia imagined a positive impression of Telenoid and interact with it. The mock-up of the Telenoid was used and compared with the teleoperated Telenoid to reveal the relation between the amount of information and communication. The result shows that the lack of information enhances users to imagine, however, at least some response from the mock-up or some information must be implemented to be imagined as a conversation partner.

From the result of Chapter 3 and 4, Chapter 5 discusses the theoretical perspective of how minimal-design robot influences the user. Then, Chapter 6 discusses conclusions and future works.

Chapter 2

Related Works

2.1 Telecommunication Robot

2.1.1 Minimal Design Approach

Sumioka *et al.* proposed a minimal-design approach to explore the minimal requirements to enhance the feeling of a human presence [93]. The feeling of a human presence can be enhanced by the physical embodiment and physical contact to the minimal-designed robot. Sumioka *et al.* revealed that the minimal-designed robot needs its torso and head for interlocutors to feel the human presence [91]. Hugvie and Telenoid are designed based on minimal design approach (Figure 1.1). Both media have head and torso and users can physically interact with them.

2.1.2 Hugvie

Hugvie is a communication device with a cushion which users have to hug it to communicate with others. Although Hugvie only transmits users' voice, by hugging it, the user will have enhanced a feeling of the counterpart in a remote location and at the same time, users will complete positively information that is lacking by the narrow bandwidth of the device.

The previous research proved that users will be relaxed and concentrated while hugging Hugvie. Sumioka *et al.* examined changes in the stress hormone cortisol before and after a conversation with Hugvie and revealed a significant reduction in the cortisol levels compared to a conversation with a cell phone [92]. Nakanishi *et al.* had a fieldwork at primary school and found that Hugvie increased the number of children who concentrated on listening to a story by the teacher talking from Hugvie [63].

Table 2.1 Basic specifications of Telenoid R3b

Height	Approx. 50 cm
Weight	Approx. 3.5 kg
Actuator	Servo motor
Controller	ARM Cortex-A8
Degree of freedom	1 for mouth, 3 for neck, and 2 for arms
Power	LiPo Battery
Exterior material	Polyvinyl chloride

2.1.3 Telenoid

Telenoid is a teleoperated android covered with soft vinyl that can transmit a remote operator's physical movement and voice. Its minimal human design allows it to resemble any person. From previous research on Geminoid [67], it can be said that Telenoid has the minimum number of channels to enable human-to-human communication. By hugging it during communication, users feel as if they are facing the remote operator and talking with him or her.

Telenoid R3b, the latest version of Telenoid, is designed to sit on the user's lap (Figure 2.1). Its basic specifications are given in Table 2.1. Through the Internet, it can be teleoperated from anywhere in the world with a laptop PC and a sensor headset (Figure 2.2). Its head motion synchronizes with the operator's head motion captured by sensors (3-axis accelerometer and 3-axis magnetometer) in the sensor headset. Speech-driven lip motion generation which generates lip motions from the operator's vocal information was used to control its jaw [31]. Telenoid has 6 independent actuators (jaw movement, yaw, pitch, and roll movement for its neck, and horizontal movement of each arm) that enable it to synchronize motion with its operator. Telenoid also moves its mouth synchronized with the operator's utterances. It can speak, look around, and give a hug.

Field experiments using Telenoid with seniors, especially seniors with dementia, have been conducted to encourage conversation. The nature of the Telenoid led to several research projects, such as philosophical studies on humans, investigating the cognitive aspects of the elderly with cognitive disorders, and a Danish national project to shorten the length of hospital stays (Patient@Home).

When using teleoperated robots whose appearance resembles their operator, *e.g.* Gemi-

Fig. 2.1 Telenoid R3b

noid [67], the personality imagined from the robot's appearance will likely match the operator's. However, in most cases, the robot's appearance is different from that of the operator. Some teleoperated robots resemble stuffed bears or non-human imaginary creatures [19, 84, 88]. Nonhuman-like appearance teleoperated robots are designed to immediately attract attention. A teleoperated robot looking like a stuffed bear is useful for such casual usages as talking to children, where operators may play a role that fits the said appearance. In such cases, interlocutors probably cannot feel the operator's presence but instead feel the presence of the character itself. Geminoids that can reflect their operator's appearance are the best communication media for increasing co-presence and reducing the appearance gap in telecommunication. However, the cost of such robots is prohibitive. To increase co-presence in daily usage, a teleoperated robot with an appearance that allows people to easily imagine any operator has to be selected.

Telenoid's goal is to create a minimal human appearance by removing as many unnecessary features as possible based on our previous experience with Geminoid [69]. Apparent individuality is reduced while maintaining the impression of a human being. That is, Telenoid does appear as a human being, but has no feature to indicate its gender or age; people

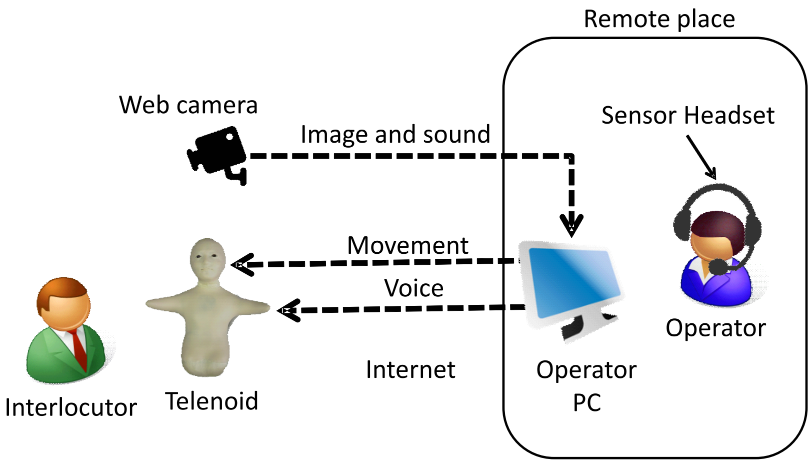


Fig. 2.2 Teleoperating system

interacting with Telenoid have the impression of facing a person, while its neutral appearance allows people to imagine any arbitrary operator.

2.2 Research Goal

There is a research about an agent giving an advice during the conversation [30] and service which supports the customer center by recognizing customer's speech and giving an advice [78]. These systems support communication by advising users. However, these require users to follow the instructions of the system which is not suitable for daily conversation. The purpose of the research is to unconsciously influence users and promote communication, instead of giving an advice during the conversation.

The minimal-designed robot is focused in this study as a communication medium to promote communication. Previous studies show that using android to communicate potentially changes human attitudes and feelings [66, 67, 118]. Therefore, mediating minimal-designed robot which can feel human presence would also influence the communication. Furthermore, how to promote communication is discussed.

How minimal-designed robot will affect the user and whether the robot provides good impression are examined in Chapter 3. This chapter discusses whether a minimal design robot can truly be handled by any user. Section 3.2 introduces an experiment comparing the impression of the operator talking from the minimal-designed robot, non-humanlike appearance robot, and video chat to reveal the effect of minimal-designed appearance and its physical presence. Section 3.3 introduces an experiment focusing on the behavior of hug to enhance the feeling of co-presence.

Chapter 4 focuses on communication support of seniors with dementia as an application of minimal-designed robot. Based on Chapter 3 and 4, Chapter 5 introduces theoretical perspective of how minimal-designed robot affect users. Then the conclusion is discussed in Chapter 6.

Chapter 3

Robot with Less Modality for Communication

This chapter discusses how minimal-design robot affects users. In Section 3.2, we compared teleoperated robots with existing communication media. Compared with other communication media such as cellphones and video chat, teleoperated robots have a physical existence which increases the feeling of co-presence. However, the appearance of a teleoperated robot is always the same regardless of the characteristics of its operator. Since people can determine their partner's personality merely from their appearance, a teleoperated robot's appearance might construct a personality which confuses the users. Our research focuses on establishing what kind of appearance of the telecommunication media could prevent confusion and increase the feeling of co-presence. In this study, we compare the appearance of three communication media (nonhuman-like robot, a human-like robot, and video chat with a projection of the speaker). The result shows that, in the case of the human-like robot, the consistency of personality judgment is better than in the case of the nonhuman-like robot. Also, we found that teleoperated robots transmit a more appropriate atmosphere due to the context, while the video chat transmits more nonverbal information, such as facial expressions.

In Section 3.3, we compared Hugvie, a device which users have to hug to communicate, and a headset, a device which users do not need to hug to communicate. We examined whether the behavior of hug complete the lack of information positively and enhance speaker's presence. We report that when a participant talks to his communication partner during their first encounter while hugging the communication medium, he mistakenly feels as if they are establishing a good relationship and that he is being loved rather than just being liked.

Our goal was to make a device that provides an opportunity to establish close relationships. We designed Hugvie to support the relationship by completing the lack of information by hugging it. Hugvie is a hugging pillow with a cell phone inserted. It only transmits the voice of the speaker. People who use Hugvie need to hug the device and hear the other's voice as a whisper. As a result, the user imagined that he is hugging the speaker and enhanced speaker's presence. Moreover, the user imagines that he and the speaker are hugging each other because they are in a good relationship and increased the feeling of being loved and liked. Such effect cannot be seen in face-to-face conversation.

From the result of Section 3.2 and 3.3, Section 3.4 discusses how minimal-design robot enhances the better impression of the operator. Telenoid and Hugvie are designed to have a neutral appearance for anyone to use. It only transmits limited motions or voice. However, in Section 3.2, we reveal that Telenoid transmits a more appropriate atmosphere due to the context, while the video chat transmits more nonverbal information, such as facial expressions. Here, we proposed a method to enhance one's affection by reducing the number of transferred modalities. By reducing the number of transferred modalities, user's affection to the robot or operator can be enhanced. Moreover, not just by transmitting, but by inducing active, unconscious behavior of users, we can increase this effect.

3.1 Related Works

3.1.1 Physical Embodiment in Telecommunication

Previous research has proved the usefulness of a physical embodiment in telecommunication. For example, Cassell *et al.* [9] showed the importance of anthropomorphic expressions such as arms and heads on embodied agents for effective communication with humans. Kidd and Breazeal [37] compared a robot and a computer-graphic agent and found that the robot was better suited for communication about real-world objects. Sakamoto *et al.* [83] compared a teleoperated robot with a video chat and found that the operator's presence is felt stronger with the robot than with the video chat.

Children with autism spectrum disorder (ASD) are motivated to interact with a humanoid robot, and the robot is used for training the social skills [76, 86, 117]. It is said that the robot has less information compared to human and is easy to recognize by children with ASD.

Several studies have been conducted on the behaviors of teleoperated agents that have taken into consideration their appearance. For example, Merola and Peña [52] revealed that an avatar's appearance can make its user more negative, confident, aggressive, or friendly. People using attractive avatars are more likely to behave friendly with others; also, they make different decisions depending on whether their avatars are taller or shorter than average [116]. People rely on information provided by an avatar's appearance and decode it by connecting cues to broader social knowledge [29]. Previous studies have focused on the effect of an avatar's appearance on communication in virtual worlds. Similar effects are likely to occur in telecommunication with teleoperated robots in the actual world. Straub *et al.* [89] reported on how people change their way of speaking when talking through a teleoperated android robot. However, few studies have been conducted so far about the ways a robot's appearance influences people. Among them, some focused on how the appearance of autonomous robots influences human behavior. Kanda *et al.* [32] compared the participant impressions about, and the behaviors of two types of humanoid robots, and found that different appearances did not affect the participant's verbal behavior, but they did affect non-verbal behaviors, such as the distance and delay of response. Although the task and interaction in these studies are quite simple, with little practical use, especially for telecommunication, their results suggest that people may be strongly influenced by the telecommunication device's appearance.

When using teleoperated robots whose appearance resembles their operator, *e.g.* Geminoid [67], the personality imagined from the robot's appearance will likely match the operator's. However, in most cases, the robot's appearance is different from that of the operator. Some teleoperated robots resemble stuffed bears or non-human imaginary creatures [19, 84, 88]. Nonhuman-like appearance teleoperated robots are designed to immediately attract attention. A teleoperated robot looking like a stuffed bear is useful for such casual usages as talking to children, where operators may play a role that fits the said appearance. In such cases, interlocutors probably cannot feel the operator's presence but instead feel the presence of the character itself. Geminoids that can reflect their operator's appearance are the best communication media for increasing co-presence and reducing the appearance gap in telecommunication. However, the cost of such robots is prohibitive. To increase co-presence in daily usage, we have to select a teleoperated robot with an appearance that allows people to easily imagine any operator.

Telenoid's goal is to create a minimal human appearance by removing as many unnecessary features as possible based on our previous experience with Geminoid [69]. Apparent individuality is reduced while maintaining the impression of a human being. That is, Telenoid does appear as a human being, but has no feature to indicate its gender or age; people interacting with Telenoid have the impression of facing a person, while its neutral appearance allows people to imagine any arbitrary operator.

On the other hand, there are systems that handle this issue in a much more direct way. Mobile Robotic Telepresence (MRP) systems are characterized by a video conferencing system mounted on a mobile robotic base [40]. Displaying its operator's image on a monitor, for example, eliminates the disadvantages experienced in the case of a teleoperated robot. A lot of research has been carried out in the field of MRP, from issues of navigation and immersion to evaluations in office and health care environments [3, 48, 103]. MRP systems do allow us to show the operator's appearance; however, the face is a displayed image with no physical embodiment.

There are robots which can have a detailed image of a face projected onto their physically detailed face, such as Retro-projected face [41]. However, since they use a projector, there are several technical issues remaining for daily life usage, such as the difficulty of recognizing the projected face under sunlight, and the fact that the projector has to be placed on the back of the head.

In Section 3.2.2.1, we compared participants' impressions on communicating through two types of teleoperated robots and through a video chat system. The robots had different appearances, one nonhuman-like (stuffed bear robot) and one with a neutral human-like appearance (Telenoid). The video chat system was used as a substitute for MRP. The benefit of using the teleoperated robot as a communication medium is increasing the feeling of co-presence to have a smooth conversation. However, the presence and information transmitted through telecommunication media give different stress levels which is also a factor which affects the smoothness of communication [73, 81]. We evaluated the impressions and stress levels, caused by the operator talking through the telecommunication media under several conversation situations to examine how the appearance representing the remote operator affected the conversation partners.

3.1.2 Misattribution of Love

Kellerman *et al.* reported that the gazing behavior of people in relationships toward a stranger of the opposite sex increased feelings of passion for each other [34]. We believe that feelings of love are also increased by communication devices that represent a partner and interacting affective behavior toward the device. We focused on hugging behaviors to support the establishment of feelings of affection.

Many devices support lovers and transmit presence. Adcock *et al.* invented a belt to support the interaction of couples who are apart [1]. Mueller *et al.* invented a coat that transmitted the feeling of being hugged remotely [58]. Many media transmit the feeling of being hugged and resemble counseling from remote places [26, 99, 102]. These are used when lovers cannot meet and address loneliness. However, such devices are designed for those who already have formed good relationships. The problem we are facing is that some people have trouble talking to others. They need a device that supports opportunities to feel affection.

Nishimura *et al.* used vibrations to simulate a heartbeat on the chests of participants and controlled the frequency of false heartbeats [65]. They verified that a preference toward female nude photos increased by modulating the frequency of false heartbeat. When such the misattribution of arousal happened, the increased heartbeat may be recognized in the participant's mind as due to the affection toward the female in the photo. Valins artificially changed the feedback of one's heartbeat and moved one's emotion [106]. Such studies control emotions by giving artificial stimulus. We believe that unconsciously doing affective behaviors toward a communication device which represents one's partner also enables users to feel affection.

Dutton and Aron studied one's affection mistakenly evoked [13]. In their experiment, male participants were contacted either on a fear-arousing suspension bridge or a non-fear-arousing bridge by an attractive female or a male interviewer who asked them to fill out questionnaires containing Thematic Apperception Test (TAT) pictures [62]. The sexual content of the stories written by participants on the fear-arousing bridge and their tendency to attempt post experimental contact with the interviewer were both significantly greater. No significant differences between bridges were obtained on either measure for participants who were contacted by a male interviewer. These results suggest that misattribution occurred and that the participants on the fear-arousing bridge established felt affection toward the female interviewer. Here, the misattribution of arousal means a mistake in explaining the aroused feelings [4]. Hugvie is designed to virtually hug the speaker to enhance the presence. That is, Hugvie is designed to create misattribution of behavior hugs.

3.1.3 Less Modality for Lovers

The best example to communicate with the limited information would be mediated conversation. Mediated conversation differs from a face-to-face conversation in the amount of information transmitted. For example, phone only transmit speaker's voice, and video chat transmits the speaker's voice and image but no physical presence. Due to the limited bandwidth, some important factors for communication such as gaze and other nonverbal information are excluded from the mediated conversation [35, 36, 51]. Recent technological progress allows richer conversations through telecommunication media that allow communicating like face-to-face [40, 67, 69, 95]. These communication media are designed to transmit as much information as possible and decrease the lack of information. However, there are communication media which are designed to limit the user's information on purpose.

For example, minimal information would be enough for lovers to communicate in some case. Adcock *et al.* invented a belt transmitting only tugging action to support the interaction of couples who are apart [1]. Tsujita *et al.* proposed the "SyncDecor" system which pairs traditional appliances and allows them to remotely synchronize and provide awareness or cognizance about their partners - thereby creating a virtual "living together" feeling [104]. Trash boxes' status of lids (open or close), the brightness of lamps, smells, and other items are synced with remote room to indirectly feel a remote person's presence. These media are running at all times for users to feel a remote person's presence in daily life without starting the other communication media. These media reduce the number of modalities to let users readily use them.

Several communication media have been produced that transmit only the feeling of being hugged [12, 26, 56, 58, 99, 102]. Since the behavior of hug requires physical contact and gives relief, Morikawa *et al.* introduced an embrace system for remote counseling [56]. These media are designed to transmit the feeling of being hugged.

We believe these media are effective because the limited number of modalities triggers users' imagination. Existing media are aiming to transmit all the modalities needed for the communication. However, by adding users' imagination, the number of modalities can be reduced to form the communication. Moreover, if the factors positively enhance the impression of the speaker, the medium can form a better communication.

3.2 Minimal-design to Prevent a Confusion

Telecommunication media are used to communicate with people in remote places. Recent technological progress allows richer conversations through telecommunication media that increase the feeling of *co-presence*. This term originated in the work of Goffman [18], who explained that co-presence exists when people sense that they can perceive others and that others can actively perceive them as well. Even though we are physically distant when using telecommunication media, media that increase the feeling of co-presence may allow more realistic conversations, reduce loneliness, and provide comfort.

Teleoperated robots have a physical body that easily reflects the operators' presence and increases the feeling of co-presence. Therefore, many teleoperated robots that can telecommunicate have already been developed [19, 40, 67, 69, 84, 88, 95]. A teleoperated robot is typically operated through the internet by an operator at a distant location. The head motion of the teleoperated robot is synchronized with the operator's, and the robot behaves and talks like the operator. The conversation partners interact with the robot as if it were the operator.

Geminoid is a teleoperated android robot whose appearance resembles its source person as much as possible to produce a feeling in its conversation partners that the original person is nearby [67]. Telenoid is a teleoperated robot with a neutral human-like appearance [69]. Instead of resembling a specific person like Geminoid, Telenoid has a minimalistic human-like appearance that generally resembles a human, without any specific features. Some teleoperated robots have a nonhuman-like appearance, such as RobotPHONE [84], Huggable [88], and Probo [19]. Their appealing appearance is similar to a stuffed bear or an imaginary creature.

The benefit of using a teleoperated robot as communication medium is to increase the feeling of co-presence. To feel the co-presence, users have to imagine someone, including that person's personality. People can accurately determine their partner's personality based on appearance [64]. However, since most teleoperated robots have unchanged appearance, this might construct personality traits that confuse the users. Our research focuses on determining what kind of appearance of the telecommunication media could prevent confusion while increasing the feeling of co-presence, in order to have a smooth conversation.

In this section, we compared participants' impressions on communicating through two types of teleoperated robots and through a video chat system. The robots had different appearances, one nonhuman-like (stuffed bear robot) and one with a neutral human-like appearance (Telenoid). The video chat system was used as a substitute for MRP. The benefit of using the teleoperated robot as a communication medium is increasing the feeling of co-presence to have a smooth conversation. However, the presence and information transmitted through telecommunication media give different stress levels, which is also a factor which affects the smoothness of communication [73, 81]. We evaluated the impressions and stress levels, caused by the operator talking through the telecommunication media under several conversation situations to examine how the appearance representing the remote operator affected the conversation partners.

Table 3.1 Conversation condition

	Free Talk (S1)	Self Introduction (S2)	Interview (S3)
Stuffed bear robot	live	pre-recorded motions and sounds	pre-recorded motions and sounds
Telenoid	live	pre-recorded motions and sounds	pre-recorded motions and sounds
Video chat	live	pre-recorded movie	live

3.2.1 Comparison of Appearance and Physical Embodiment

Participants talked with operators through one of the three media. Then they evaluated the personality of the operators based on the conversation. Here, personality is the participants' impressions of the operator talking through the medium.

We made between-participants comparisons, and each subject had several conversations with different operators using only one medium. We presumed that the degree of mixed feelings about the personality of the operator in telecommunication depends on the conditions under which the conversation is held. Therefore, we set up three types of situations and interactions (Table 3.1).

This paper did not use face-to-face conversation as a baseline. Instead, we simply compared the results obtained with the different communication media. Past studies have already shown that, compared with face-to-face conversation, people feel different when talking through a communication medium [70, 73, 81]. Thus, we evaluated how these impressions are formed diffused through different communication media, and what are the factors that influence the smoothness and lead to less confusing conversation.

3.2.1.1 Communication media

We used three kinds of communication media:

- A teleoperated robot that resembles a stuffed bear whose appearance is far from the operator's appearance and is similar to RobotPHONE [84]
- Telenoid as a teleoperated robot with a human-like appearance
- A video chat system that lacks a physical existence but transmits an exact image of the operator's appearance.

(a) Telenoid (b) Stuffed bear robot (c) Video

Fig. 3.1 Communication media used in experiments

To control the size and motion of the physical media, we covered the upper body of Telenoid with a stuffed bear costume (Figure 3.1(b)). Telenoid's teleoperation system is shown in Figure 3.2. Telenoid has nine independent actuators (vertical movement for each eye, horizontal movement for both eyes, jaw movement, yaw, pitch, and roll movement for its neck, and horizontal movement for each arm) that enable it to synchronize motion with its teleoperator. To examine the effect due to the appearance or the embodiment, and not to the movement, we limited and controlled the movements. Since a stuffed bear robot cannot move its eyes and the video chat system does not display hand gestures in this experiment, Telenoid was controlled to move only its neck and mouth. Telenoid's head motion was synchronized with the operator's head motion. For example, the operator's nodding or tilting motion was captured by a web camera, recognized by image processing, and converted to motor commands for Telenoid's motions. Telenoid also moved its mouth in sync with the operator's utterances. Speech-driven lip motion generation, which generates lip motions from the operator's vocal information, was used to control its jaw [31]. The stuffed bear robot was teleoperated with the same system.

We used a 27-inch monitor in the portrait orientation for the video chat so that the monitor size was close to the robots' size. The monitor and speaker for the video chat system were directly connected to the video camera and a microphone in the operator's room to transmit voice and image with less delay.

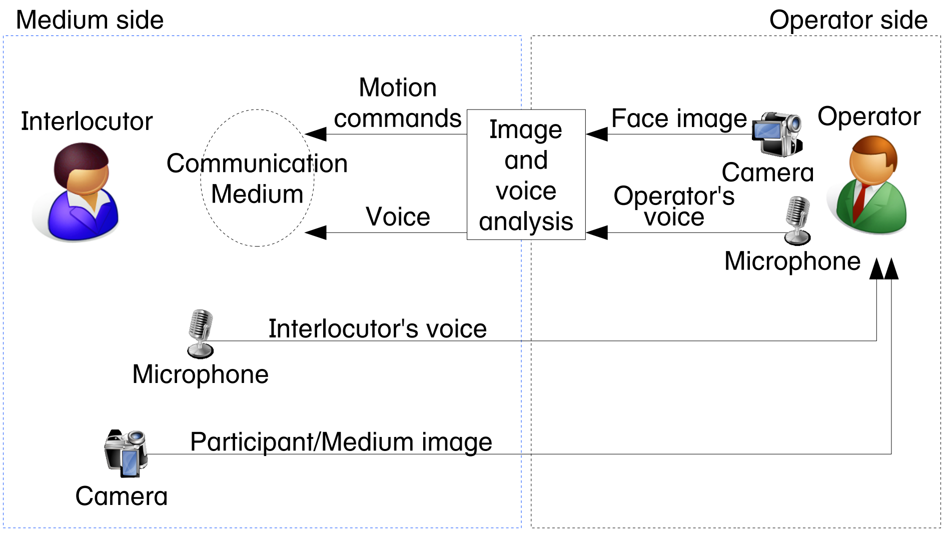


Fig. 3.2 Teleoperation system for Telenoid and stuffed bear robot

3.2.1.2 Experimental room

Figure 3.3 shows the equipment alignment in the experimental room. The operator can see the entire room through the video camera to recognize both the medium in use and participant's behavior (Figure 3.4). The operator's voice, output from the communication medium, must have the same quality and volume among all three media. Therefore, instead of using the audio output devices embedded in each medium, we used the same speakers placed on the side of the communication media. The operator can hear the sound in the experimental room via a microphone placed under the participant's chair.

3.2.1.3 Procedure

We arranged three types of conversation situations with three different operators about different topics through the same medium (Table 3.2):

S1: a relaxed conversation in which both the participant and the operator talked
S2: self-introductions in which only the operator talked
S3: interviews in which the participant did most of the talking

Here, different researchers played the role of operators in the three situations. To investigate the effect of each medium in forming an appropriate atmosphere to each situation, we arranged the first two situations as low-stress, and the third as a high-stress situation. For S1, we arranged ten minutes of free talk with no restrictions, to allow the participants to get

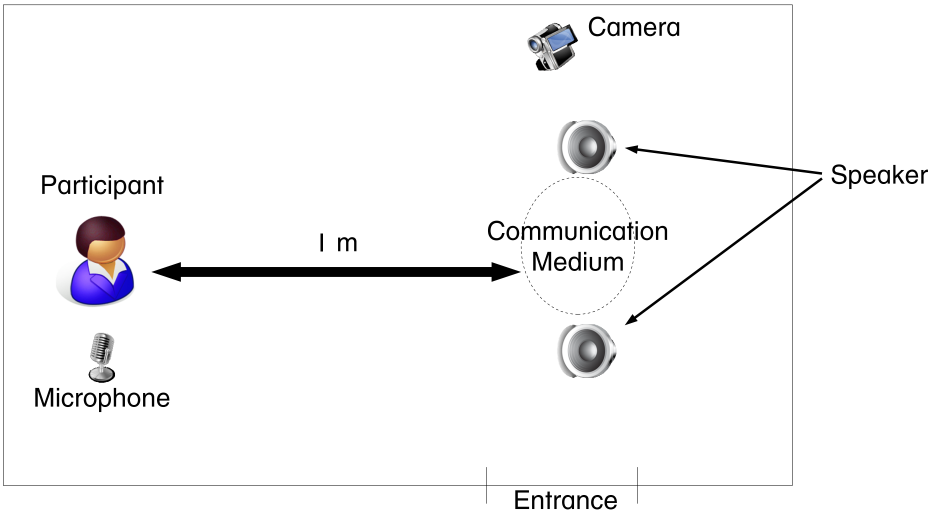


Fig. 3.3 Experimental setup

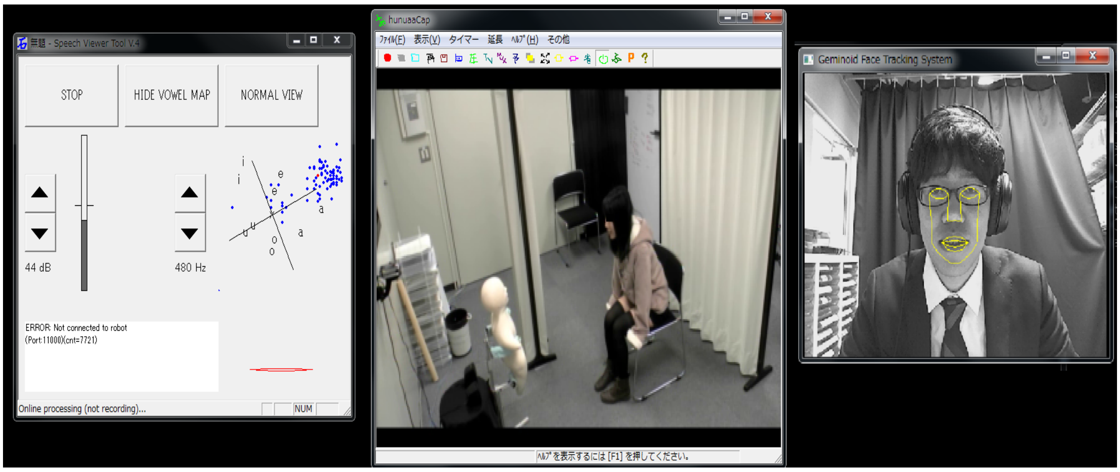


Fig. 3.4 Screenshot of operator interface (left: lip motion generation system, center: view of experimental room, right: head motion recognition system)

used to the communication medium. In S2, the operator introduced himself for two minutes. Since the participant passively listens in this situation, the duration was shorter than in S1. For S3, the operator interviewed the participants about the experiment. The duration of S3 depended on the participant's answers, and the average was 151 seconds ($SD = 48$). Finally, we briefly interviewed the participants and asked for their impressions about the communication medium and the operator.

Table 3.2 Conversation situations

	Free Talk (S1)	Self Introduction (S2)	Interview (S3)
Role of operator	university student	university student	project manager
Duration	10 minutes	2 minutes	average 151 seconds ($SD = 48$)
Degree of stress	low	low	high

S1 was carried out first, for subjects to get used to the medium. S3 was carried out last, and the participants were informed in advance that an interviewer will interview them about the experiment.

Figure 3.5 and the following show the experiment procedure:

1. Participants receive an explanation, sign a consent form in the waiting room, and move to the experimental room.
2. S1 begins: a 10-minute free talk with a university student.
3. After ten minutes, the experimenter (a different person from the operator) stops the conversation, hides the medium behind a curtain, and asks the participant to answer a questionnaire.
4. After the participant finishes the questionnaire, the curtain is removed, and S2 begins: a 2-minute self-introduction by a university student.
5. After S2 is finished, the experimenter hides the medium again, and asks the participant to answer a questionnaire.
6. After the participant finishes the questionnaire, the experimenter explains that the manager of the lab wants to interview the participant about the experiment and that he will talk through the communication medium since he is in a different location. The curtain is removed and S3 begins: interview.
7. After the interview is finished, the experimenter hides the medium, and asks the participant to answer a questionnaire.
8. After the participant finishes the questionnaire, the experimenter asks about his/her impressions about the communication medium used, and whether the participant noticed that pre-recorded movies and motions were used in S2 and S3.

In S2, we used a pre-recorded data for all three media. Prior to the experiment, a single set of video, audio and motion data for S2 was recorded, and in each experimental session,

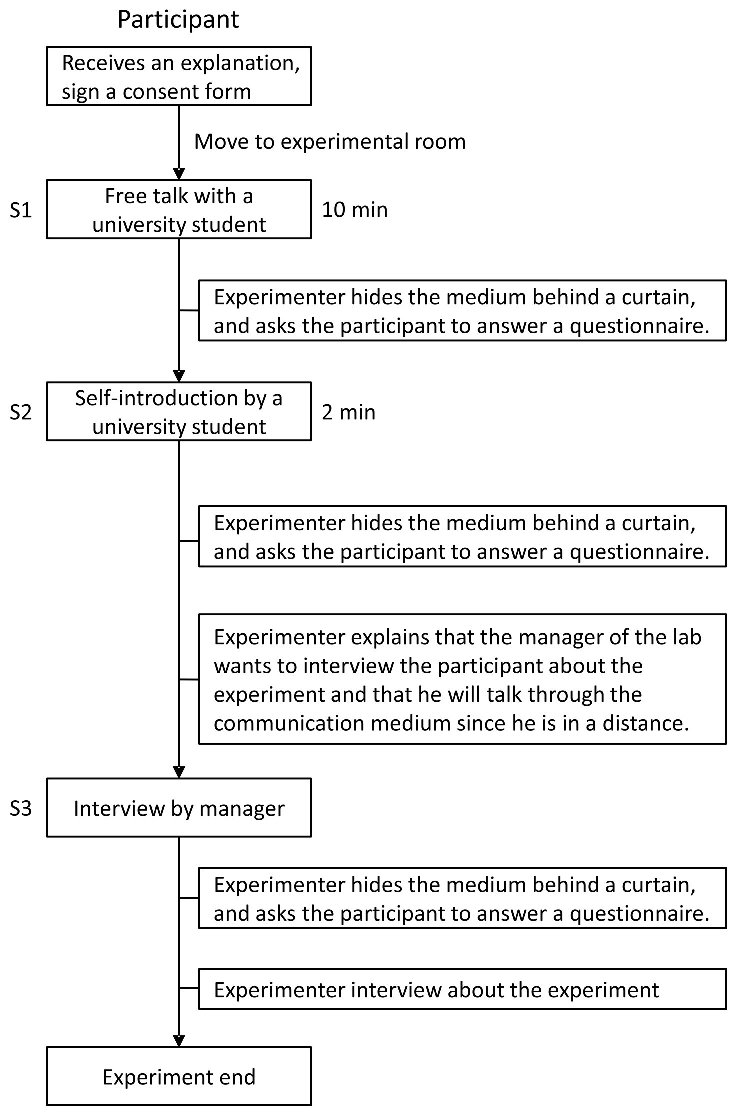


Fig. 3.5 Experiment procedure

we played back the data through each medium (audio and motion data for the robots, and video and audio data for the video chat). This was to make sure that the conversations are the same for all participants, since in S2 (self-introduction by the operator) we expected no interaction between the operator and the participant.

In S3, the operator played the role of manager of the experiment. He wore a business suit, spoke formally to pressure the participants in contrast with the other conditions, and asked prepared questions for every participant. Also, in S3, the operator performed live conversations in the video chat condition. We recorded all the conversations in the video chat condition, including motion data, and used them for the two teleoperated robot conditions. Here, the recordings were split into two types of fragments: when the operator was speaking, and when the operator was listening. As the conversation in S3 was a sequence of question and answers where the operator always asked questions, the recordings could be fragmented easily. In the teleoperated robot conditions, which was run after all the video chat condition sessions, we chose one recording from the video sessions randomly and used fragments from it.

3.2.1.4 Questionnaires and evaluations

In this experiment, we used the Japanese Big Five personality test, a 60-adjective checklist that represents five factors of personality (extraversion, neuroticism, openness to experience, agreeableness, and conscientiousness) that was developed by Wada [109] and translated from the Adjective Check List by Gough and Heilbrun [20]. Since some adjectives are difficult to translate into Japanese, except for the translated adjectives, Wada added some adjectives that are appropriate for each factor so that the number of adjectives equals to the original test. Therefore, not all adjectives in the Japanese test match those in the English test. Each factor has twelve different adjectives. All adjectives are rated on a 7-point scale, ranging from 1 (strongly disagree) to 7 (strongly agree). Although this questionnaire was designed to test one's own personality, it can also be used for testing the personalities of others. For example, Naumann *et al.* [64] evaluated impressions about people in photographs using this test.

How one's impression about the personality of the interlocutor is affected by the means of communication can be evaluated by comparing the impressions obtained in face-to-face conversations with those obtained via telecommunication. In telecommunication, it is important to consider whether the person's original personality is transmitted correctly; however, it is more important to make communication smooth, *i.e.*, prevent the listener (the one who is facing the medium) from getting confused. Therefore, we evaluated whether the listeners get confused or not.

A participant will likely evaluate the same operator's personality in a similar way, even though the environment (medium) is changed. Therefore, we made sure that no participant evaluates the same experimenter twice. If the personality is distorted by the medium, participants will sometimes feel like they are talking with the operator, and sometimes like they are talking with the teleoperated robot itself, as described in Figure 3.6. After the conversation, the participant may not be able to clearly judge the operator's personality because the impression about the operator will be mixed with that about the teleoperated robot. Therefore, we measured the inconsistencies in the questionnaire results about the operator's personality.

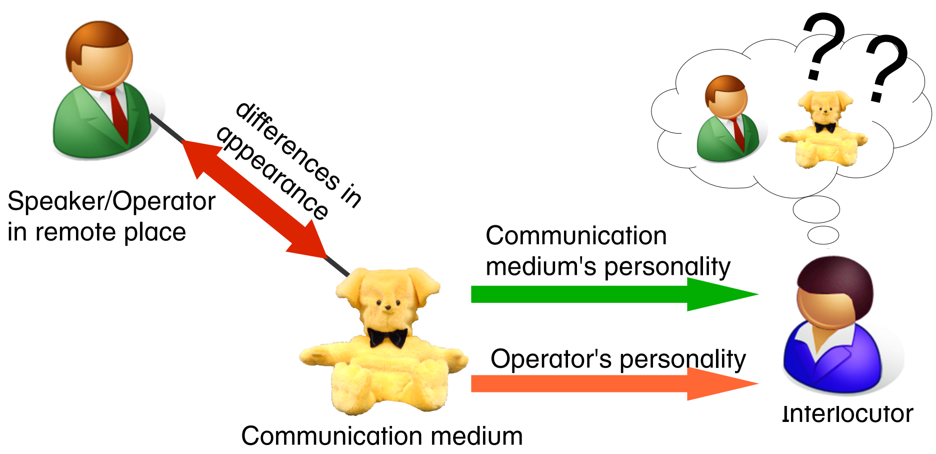


Fig. 3.6 Personality distortion

To evaluate the inconsistency of the questionnaire answers about the operator's personality, we used Cronbach's alpha, a coefficient of reliability [11]. Cronbach's alpha is used to measure the internal consistency of an answer. As described by Tavakol and Dennick [98], a low value of alpha could be due to a low number of questions, poor interrelatedness between items or heterogeneous constructs. When we measure the consistency of the participants' answers, we usually assume that the answers are derived based on a stable information source, such as fixed stimuli. However, in the case of our experiment, the information source may have been unstable due to the nature of the medium used. Participants guess the personality of the experimenter based on what they receive through mediated communication. Past studies have shown that mediated communication distorts impressions [70, 73]. If this distortion occurs in a consistent way, the participants receive a consistent impression. However, if the distortion occurs inconsistently, it functions as an inconsistent information source, and, as a result, the answers derived from this inconsistent information source will lack consistency. By using Cronbach's alpha, our idea is to measure the stability of the information source, that is, to see the distortion characteristics of each communication medium.

The Japanese Big Five test was confirmed to have high consistency ($\alpha > 0.84$) in tests with 350 participants who judged their own personalities [109]. Therefore, if the alpha coefficient of the participant answers to the Big Five questionnaires about the operator's personality is low, we can infer that the participants failed to infer the operator's personality. If they correctly evaluated the operator's personality, the medium is not distorting the transmitted personality. George and Mallery [16] provided the reliability criteria in Cronbach's alpha

Table 3.3 Reliability criteria in Cronbach's alpha (α: Cronbach's alpha)[16]

~ 0.5	0.5 ~ 0.6	0.6 ~ 0.7	0.7 ~ 0.8	0.8 ~ 0.9	0.9 ~
inacceptable	poor	questionable	acceptable	good	excellent

(Table 3.3). With Cronbach's alpha, we can evaluate whether the consistency of the answers is sufficiently high using the above criteria to determine whether the personality is correctly inferred, without direct comparisons among the judged personalities in each medium.

The comfortableness (level of stress) of talking is different in computer mediated conversations and face-to-face conversations [73], and we think such a difference also manifests itself depending on the various communication media. Therefore, after each conversation, we asked the participants "Did you feel nervous while facing?" to evaluate the levels of stress experienced, using a seven-point Likert scale. Since the stress might differ in different conditions, we provided both high and low stress conditions (Table 3.2).

3.2.1.5 Target participants

Forty-six Japanese university students, whose average age was 21.0 ($SD = 2.0$), joined the experiment (34 males and 12 females). We divided them randomly into three groups (Telenoid, stuffed bear robot, and video chat). Two were omitted from the analysis due to experiment failure. We collected the following datasets: 16 for the stuffed bear robot (14 males and 2 females), 16 for Telenoid (12 males and 4 females), and 12 for the video chat (7 males and 5 females). All of them answered to the interview that they had never met the experimenters they talked with. All participants provided written informed consent. This experiment was approved by the ethics committee of Advanced Telecommunications Research Institute International (No.11-506-1).

3.2.2 Results

3.2.2.1 Consistency of Personality Judgment

Almost all the factors of the Big Five test used in our experiment had high consistency ($\alpha > 0.80$). Only the stuffed bear robot had low consistency ($\alpha < 0.70$) on some factors under some situations (Table 3.4). Since the use of specific adjectives may cause a decrease in the consistency of the factor, we measured the correlation of each adjective with low consistency in the factor with the total scores of the other adjectives in the factor. If the correlation was

Table 3.4 Cronbach's alpha on each situation (E: extraversion, N: neuroticism, O: openness to experience, C: conscientiousness, A: agreeableness, *: $\alpha < 0.7$)

	E	N	O	C	A
S1	0.911	0.858	0.818	0.821	0.882
S2	0.898	0.882	0.878	0.769	0.641*
S3	0.634*	0.844	0.910	0.666*	0.746

(a) Stuffed bear robot

	E	N	O	C	A
S1	0.871	0.710	0.779	0.803	0.771
S2	0.884	0.902	0.874	0.882	0.840
S3	0.860	0.884	0.898	0.754	0.867

(b) Telenoid

	E	N	O	C	A
S1	0.893	0.932	0.888	0.881	0.721
S2	0.918	0.921	0.933	0.868	0.837
S3	0.838	0.931	0.959	0.923	0.802

(c) Video chat

low or negative, it is possible that the adjective has strong effect in decreasing the consistency of the factor. Table 3.5 shows the top three adjectives with low or negative correlation to the consistency scores derived from the remaining adjectives.

3.2.2.2 Adaptability to situation

Four participants who noticed that the second or third conversations used pre-recorded movies and motions were omitted from the analysis, since we needed to measure the mental state in live conversations. There were no significant differences among the communication media as far as the stress of talking to the medium and facing it were concerned. However,

Table 3.5 Top three adjectives with low/negative correlation to the total scores in the Big Five factors, where Cronbach's alpha was low (*: inverse)

	Adjective	r	Cronbach's alpha without this adjective	Difference from original alpha
1	straightforward	-0.197	0.716	0.075
2	kind	0.047	0.663	0.022
3	supportive	0.149	0.642	0.001

(a) Agreeableness for stuffed bear robot in S2 (original alpha: 0.641)

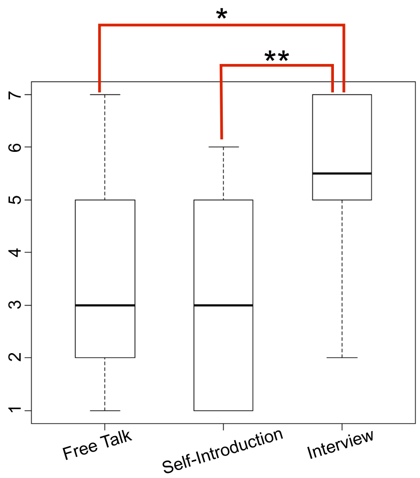
	Adjective	r	Cronbach's alpha without this adjective	Difference from original alpha
1	plain*	-0.359	0.734	0.100
2	cheerful	-0.128	0.677	0.043
3	unsociable*	-0.075	0.675	0.041

(b) Extraversion for stuffed bear robot in S3 (original alpha: 0.634)

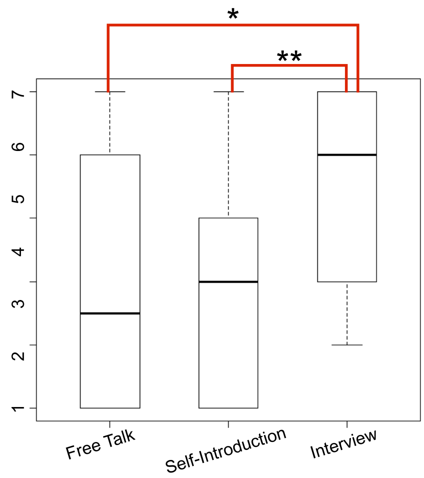
	Adjective	r	Cronbach's alpha without this adjective	Difference from original alpha
1	easily bored*	0.036	0.685	0.019
2	thorough	0.093	0.683	0.017
3	indifferent*	0.135	0.668	0.002

(c) Conscientiousness for stuffed bear robot in S3 (original alpha: 0.666)

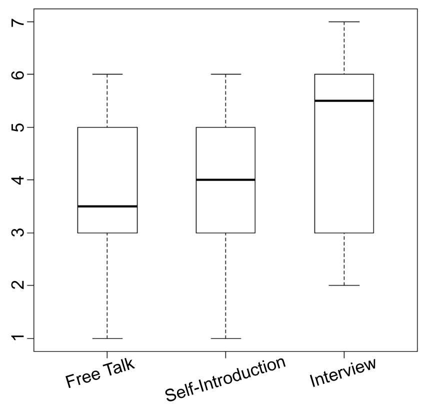
there were significant differences in stress levels among the three situations, while facing the same medium. Figure 3.7 shows the degree of stress while facing each medium. Multiple comparisons using Scheffe's paired comparison method showed a significant difference between free talk and interviews ($\chi^2(2) = 7.51$, $p < 0.05$), between self-introductions and interviews ($\chi^2(2) = 12.22$, $p < 0.01$) in the case of the stuffed bear robot, between free talk and interviews ($\chi^2(2) = 9.12$, $p < 0.05$), and between the self-introductions and interviews



(a) Stuffed bear robot



(b) Telenoid



(c) Video chat

Fig. 3.7 Multiple comparisons of stress while facing medium (*:$p < 0.05$, **:$p < 0.01$)

($\chi^2(2) = 9.78$, $p < 0.01$) in the case of Telenoid. We used non-parametric tests, since normalities within each medium were rejected by the Shapiro-Wilk test (stuffed bear robot: $W = 0.895$, $p < 0.01$, Telenoid: $W = 0.869$, $p < 0.01$, video chat: $W = 0.920$, $p < 0.05$). As for gender, we did not have significant differences for any measures.

3.2.2.3 Interviews

After the experiment, we interviewed the participants about their impressions on each medium. Some participants felt the stuffed bear robot was cute or doll-like; only one participant felt like the participant was talking to a human. For the Telenoid, most participants felt it was scary or creepy.

We also asked participants whether they noticed that pre-recorded movies and motions were used. Four participants (two for Telenoid and two for the video chat condition) noticed that pre-recorded movies and motions had been used, but no one noticed it in the stuffed bear condition. Two participants in the video chat conversation asked the interlocutor some questions, and noticed the video was pre-recorded because their questions were ignored. The other two participants who noticed the recordings in the Telenoid condition did not ask any questions but they still had doubts.

3.2.3 Discussion

We compared how the appearance of the telecommunication media affects the participants' impressions about their interlocutors. We found differences between the human-like and nonhuman-like appearance of the teleoperated robots, regarding the consistency of the personality judgment. We also found differences in the stress caused by the operator, between physical and displayed faces on the stress.

3.2.3.1 Human-like and nonhuman-like appearances of teleoperated robots

Only the stuffed bear robot showed low consistency ($\alpha < 0.70$) on some factors under some situations (Table 3.4). According to George and Mallery [16], a coefficient under 0.7 means the answer has less reliability. The Japanese version of the Big Five questionnaire has been proved to have high consistency [109]. Therefore, the low consistency in the result indicates that the participants had mixed feelings about the operator and about the communication medium itself. In the questionnaires, they sometimes judged the operator's personality, and sometimes the personality imagined from the operator's stuffed bear appearance. Table 3.5 shows the list of the top three adjectives which have low or negative correlation with the total scores of the other adjectives in the Big Five factors. These adjectives cause the decrease in the consistency of the questionnaire. Except for some adjective in Table 3.5, the value of adjectives in S2's Agreeableness factor and S3's Extraversion factor will exceed 0.70. That is, the participants selected the adjectives contradictory to the other adjectives in the factors.

The adjectives are *straightforward* in S2's Agreeableness factor and *plain* in S3's Extraversion factor. For S3's Conscientiousness factor, no specific adjective, but all adjectives evenly cause a decrease in the consistency of the factor. The participants may imagine some specific personality from the appearance of the stuffed bear related to the adjectives which decrease the consistency of the factor when evaluating the operator. In fact, it seems difficult to evaluate the operator's personality from the appearance of the stuffed bear robot. When we asked the participants about their impressions about the stuffed bear robot, some described it as cute and some said that it did not feel like talking to a person.

When the appearance of a robot becomes closer to a human being, people tend to have strange feelings toward it. These feelings are explained by Mori [55] as "uncanny valley". The impressions the participants had towards Telenoid can thus be explained by its human-like appearance. Also, previous research [69] has shown that Telenoid is perceived as strange, but the users easily get used to it. This might be the reason why participants judged the operator's personality with high consistency, despite the fact that they felt strange.

We also found that a human-like appearance caught the attention of communication partners more easily than a nonhuman-like appearance. Four participants (two for Telenoid and two for the video chat condition) noticed that pre-recorded movies and motions were used, but no one noticed this in the stuffed bear condition. Two participants in the video chat conversation asked the interlocutor some questions and realized it was a recorded video because their questions were ignored. The other two participants who noticed the recordings in the Telenoid condition did not question the operator, but they still had their suspicions, likely caused by the unnaturalness in the robot's movements. No one noticed the fact that the videos were pre-recorded in the stuffed bear condition, which suggests that the participants were not concentrating on the stuffed bear robot's movements. In fact, one participant in the stuffed bear condition did not look at the medium at all while the operator was talking. A teleoperated robot with a nonhuman-like appearance might catch one's attention at first glance; however, a teleoperated robot with a human appearance will attract more attention during conversations.

We also infer that low consistency tends to occur in situations with few interactions (self-introductions and interviews) because the participants obtain less information about the operator from the conversations. If the self-introduction and interview situations were as long as the free talk, the consistency might not decrease in the stuffed bear robot condition. However, even though in the case of the Telenoid, short interactions through it produced enough consistency, in the case of the stuffed bear, the low consistency comes from its characteristics, not just the amount of interaction.

3.2.3.2 Physical and displayed faces

Figure 3.7 does not show a significant difference between the amount of stress in the three media; however, there are differences among the media when we focus on the situation dependency. The teleoperated robot with a physical face tends to reduce the feelings of anxiety in some situations, but the video chat with a displayed face does not. We arranged the interview situations to be more stressful than the other situations. When using the two teleoperated robots, the participants felt significant differences between S2 (self-introduction) and S3 (interview). That is, participants felt more pressure in the interview situation. As for Telenoid, we also found a significant difference between S1 (free talk) and S3 (interview). There was a similar tendency for the stuffed bear robot, although no significance was found. From these results, we can say that the conversations in the interview situation (S3) did produce more stress than S1 or S2. However, when using the video chat, the stress scores of the subjects did not vary among the three situations.

Compared with the other teleoperated robots, the video chat does not show a physical face. This lack might result in a weaker feeling of co-presence and might construct a less appropriate atmosphere for the situation. Thus, the participants felt no difference in stress among the three situations using the video chat. Although Telenoid and the stuffed bear robot were viewed as creepy or cute, we found that physically detailed faces tended to transmit appropriate stress based on the situation.

The difference between the video chat and teleoperated robots is not just the physical embodiment. The video chat can transmit facial expressions and other nonverbal information in detail. Although the experimenters who spoke through the video chat were instructed to be strict in S3, their eye gaze or facial expression were not controlled throughout the three conditions (S1 - S3). This is one of the essential differences between teleoperated robots and video chat. Controlling and restricting such nonverbal information could lead to non-proper evaluation results. As shown by the high coefficient values, the video chat seemed to transmit the operator's personality very well. This could be because the video chat transmitted more nonverbal information compared with the teleoperated robots. However, such rich information may result in transmitting constant pressure regardless of the operator. The constant scores of the three conversations of the video chat results are not due only to the lack of physical faces, but also to the rich information.

3.2.3.3 Limitations

In this paper, we did not focus on the effect on the operators. In Yee and Bailenson's study [116], the users of tall avatars were more confident in a bargaining task than those assigned short avatars, and were less likely to accept unfavorable decisions. Operators using teleoperated robots can be influenced by the appearance of the robots [89]. If the teleoperated robot's appearance is a cute animal, the operator might talk nicely or sweetly. In our experiments, we used pre-recorded movies and motions as much as possible to remove any effect of the robot's appearance on the operator.

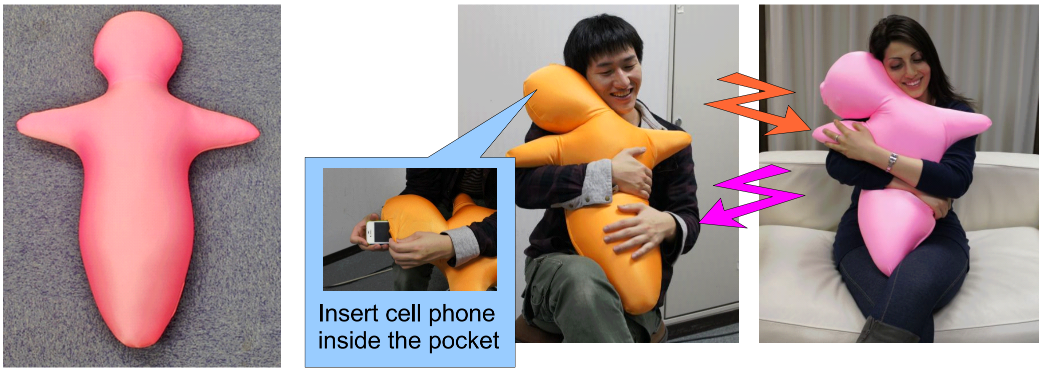
In this paper, we considered only the appearance of the teleoperated robot. MRP systems usually have wheels that enable navigation. This means that the robot can adjust its personality space, which may control the pressure based on the situation [22]. Telenoid and stuffed bear robots cannot move around but they can hug and be hugged. Previous research proved that hugging a medium enhances the feeling of co-presence and may establish a closer relationship [46]. When taking into consideration these original ways of using teleoperated robots, the results may differ.

3.2.4 Summary

In this paper, we compared the impressions of users about the operator's personality as if was transmitted through three communication media, *i.e.*, two types of teleoperated robots and video chat. By remeasuring the consistency in questionnaires about the operator's personality, we found that, when the communication medium does not have a human-like appearance, the operator's personality that is transmitted through the medium is mixed with the personality imagined from the medium and the interlocutor gets confused. Such problems can be solved by giving the communication media a neutral human-like appearance, which will have less influence on personality construction, resulting in less conflict with the operator's original personality.

We also found that teleoperated robots and video chat produced different feelings of stress during the conversations. The teleoperated robots' physical existence help form a more appropriate atmosphere for each situation.

Therefore, we conclude that a teleoperated robot with a human-like physical face will be better for preventing confusion than a nonhuman-like teleoperated robot or a video chat. It will also likely to form an appropriate atmosphere for each situation. However, suitable situations exist for all above-mentioned communication media. If a communication medium



(a) Hugvie (b) Hugvie usage

Fig. 3.8 Hugvie and its usage

transmits too much information, the interlocutor might experience stress from the operator. When we want to exert pressure in a conversation, we should use the video chat, and we should use a teleoperated robot when we want to form an appropriate atmosphere for the situation. To disguise our personality or make the interlocutor imagine a friendly person, using a stuffed bear robot is better than either video chat or Telenoid.

In this paper, we discussed the problem of the appearance of the communication media, and identified the usefulness of remeasuring the consistency of the answer to the questionnaires. We believe that this study will help design communication media that are appropriate for various situations.

3.3 Hug to Encourage a Good Relationship

In this paper, we introduce a communication medium which triggers user to establish a good relationship with others through the medium. We designed the communication medium "Hugvie" which users have to hug to use (Figure 3.8). Hugvie is a communication device with a cushion which users have to hug it to communicate with others. Although Hugvie only transmits users' voice, by hugging it, user will have enhanced feeling of the counterpart in remote location and at the same time, users will complete positively information that is lacking by the narrow bandwidth of the device.

In daily life, we often complete information that is lacking. For example, when you ask some question to a customer center staff and if her voice is nice and she responds so kind to you, you may imagine her as a nice person. Although you are talking through a cell phone and it only transmits voice, you might imagine an appearance of a gentle lady in your mind. You do not know her appearance and personality. However, you completed the appearance and personality positively from the information (nice voice and kind reaction) transmitted from the cell phone.

In this case, person who called the customer center completed the lack of information (appearance and personality) positively from the factors (nice voice and kind reaction) which he received passively. However, our hypothesis is that such factors can also be generated actively, instead of just passively perceiving received information. One way to make it, we think, is to hug the speaker virtually through the communication medium. If the user hugs it, instead of just holding it at his ear or facing the device, the user may feel like hugging the person in remote and feel enhanced presence of the person. We believe that the lack of the information transmitted through the communication media can be completed and enhanced by actively behave or imagine toward the communication media. Here, the speaker can limit factors which give negative impression and transmit the factors which trigger to impress positively to improve the impression of the speaker. This method is similar to make-up, which changes your appearance to improve the impression. Both give better impression toward the opponent and help constructing better relationship.

In this paper, we compared Hugvie, a device you have to hug to communicate, and a headset, which you do not need to hug to communicate. We examined whether the behavior of hug complete the lack of information positively and enhance speaker's presence. In the following sections, we will first describe some related works. In Section 3.3.1, we describe the details of the experiment and we show the results in Section 3.3.2. Based on the results, we further discuss the possibility to enhance co-presence of remote person by devices that induce users' active behavior.

3.3.1 Hug and Communicate

3.3.1.1 Outline

To reveal the effect of the hug behaviors, we arranged **with-hug** and **without-hug situations**. We compared the former with Hugvie and the latter with a Bluetooth headset to verify our hypothesis (Figure 3.9).

The participants were limited to males, like Dutton and Aron's experiment [13]. We focused on active affection, defined as affection toward the female, and passive affection, defined as the affection the participants thought they received. To measure the effect of the

(a) with-hug situation (b) without-hug situation

Fig. 3.9 Scene using media

hugs, we controlled and ignored the influence of the conversation contents as much as possible. We recorded the female voices to establish conversations with the male participants to control the conversation between the subjects.

We created a relaxed environment in the experimental room by placing magazines and a legless chair on the rug with indirect lightning and arranged and operator's room outside of the experimental room (Figure 3.10). The participants were told that the female was in an identical environment in a different room. Since we used a single medium (Hugvie or Bluetooth headset) on each participant, we compared the medium between participants.

3.3.1.2 Apparatus

We compared the with-hug situation using Hugvie and the without-hug situation using a Bluetooth headset (Figure 3.12). Hugvie is a huggable pillow resembles a human with a pocket on its head where user places his cell phone or a similar device to listen to the interlocutor's voice. Hugvie has a flexibility texture filled with microbeads, and the following are

Fig. 3.10 Experimental room

its specifications:

- Size: height 800×width 550×depth 200 (mm)
- Weight: approximate 600 g (device included)

3.3.1.3 Procedure

We conducted our experiment as follows:

1. The participants talked for three minutes with a male experimenter through one medium (Hugvie or Bluetooth headset) to get used to it. Conversation topics included current events to suggest that the conversations were live and not recorded.
2. The participants waited in the experimental room for ten minutes. While waiting, they got used to the experimental room by flipping through magazines, but they were not allowed to use their cell phones or other electronic devices.
3. They got call from the medium and first introduced themselves for around 30 to 60 seconds to the female experimenter, whose voice was recorded. To prevent the participants from noticing that the experimenter's voice is recorded, they are prohibited from questioning their female interlocutor due to privacy concerns. The female experimenter introduces herself first and lets the participant introduce himself next to begin

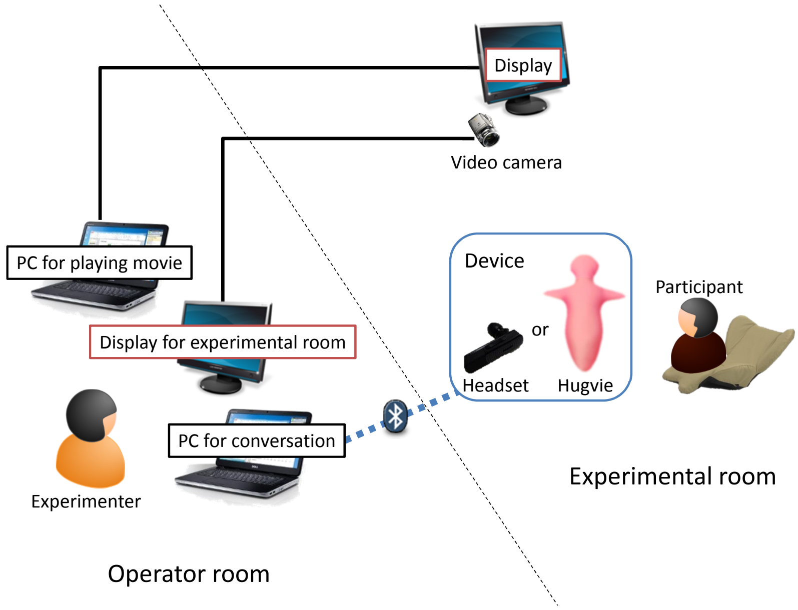


Fig. 3.11 Tele-operation system for Hugvie and Bluetooth headset

Fig. 3.12 Bluetooth headset (Princeton Technology, Ltd. PTM-BEM6)

the conversation. The moment to play the female experimenter's voice was decided by the experimenter who was listening to the participant.

4. After their introduction, the participants watch the movie for 30 minutes with the medium who remains on the cell phone.
5. The experimenter tells the participants to disconnect the medium. Then the experimenter tells them to wait briefly while the next experiment is being prepared. The participants are also given permission to call their female conversation partner using the medium.

6. After the participants call their female conversation partner or do not call for 15 minutes, the participants answer questionnaires and are interviewed.

Conversation while watching the movie was also discouraged so that they could concentrate on the movie. Only one participant noticed that the voice is recorded; he was removed from the study. The female experimenter's reactions and such noises as laughter and sneezing while watching the movie were recorded and played simultaneously through the medium.

3.3.1.4 Evaluation

We focused on two kinds of affection: active affection, which is affection toward the female, and passive affection, which is the affection the participants thought they received. However, emotions are very naïve, and measuring them is very difficult by asking directly whether the participant felt affection. Therefore, we indirectly measured the amount of the feelings of affection. We evaluated whether participants called the female experimenter back to measure the active affection. We believe that participants will call back after watching the movie if they are interested in the experimenter and want to talk more. To measure the passive affection, we created a loved-liked scale, based on a love-liking scale translated from Japanese [15]. The sentences in love-liking questionnaire were changed to passive sentences. 13 items asked about loved and liked feelings on a 9-point scale, and we compared the total points. If the participants felt affection from the interlocutor, the total points of the loved will exceed the liked.

We also asked whether the participants felt the interlocutor's presence and other characteristics of tele-presence devices in the questionnaires. During the experiment, we noticed the impression toward the movie might change due to the medium. Therefore, for the latter participants, we added the questionnaire asking about the impression toward the movie on a 7-point scale to evaluate the mental states during watching the movie.

3.3.1.5 Target participants

Participants included 21, 18 to 22 year old male Japanese university or undergraduate students whose average age was 20.0 (SD = 1.6). Six (including the above participant who recognized that the experimenter's voice was recorded) who failed to follow the rules were omitted from the analysis. Eight with-hug situations and seven without-hug situations were used for our analysis. Each has four who answered to the questionnaire asking about the impression of the movie.

Table 3.6 Impressed scenes on movie

Scenes in movie	t-value	p-value
Chasing cat	0.193	0.426
Watching the clock	0.228	0.413
Delivering lunch	1.457	0.094
Eating lunch	-0.909	0.803
Love advise	1.394	0.103
Boy saying "love you"	1.989	**0.044**
Girl and boy talking	1.207	0.134

3.3.2 Results

3.3.2.1 Phone call back

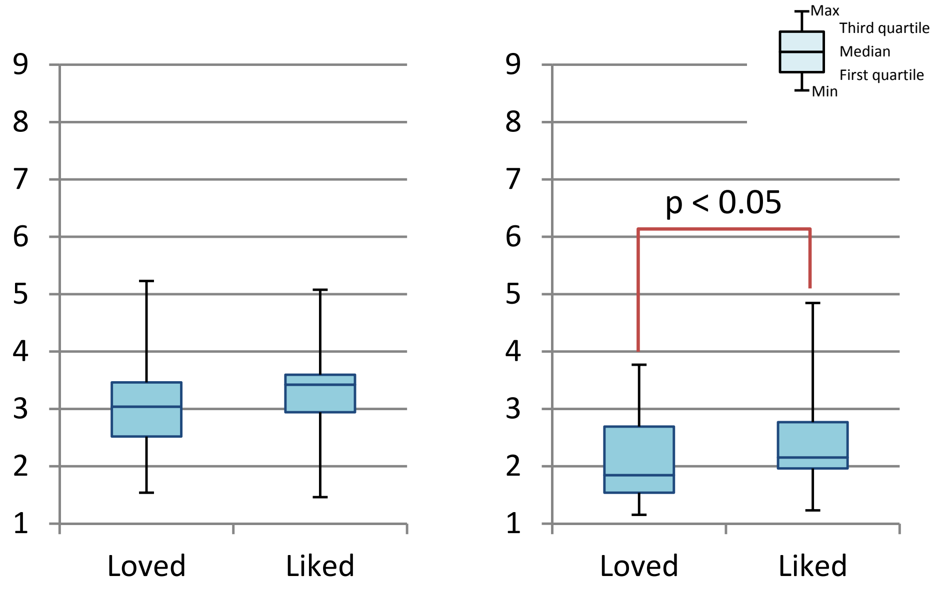
Two with-hug situations and three without-hug situations called the interlocutor while waiting. When asked why they called back, three participants said that they wanted to use the device. Most who did not call back said that they did not do so because the interaction was short and they had no reason to call back. The reason for calling back was not related to whether the participants felt affection toward the interlocutor.

3.3.2.2 Loved-liked scale

Those whose total points of loved items exceeded the liked items were four in the with-hug situation and none for the without-hug situation. We used a paired t-test and only found significant differences for the without-hug situation ($t = 2.54$, $p = 0.044$) and not for the with-hug situation (Figure 3.13). In the without-hug situation, the liked points significantly exceeded the loved points. We compared the loved and liked points between the media and found significant differences in both loved ($t = 1.82$, $p = 0.046$) and liked ($t = 1.39$, $p = 0.095$) (Figure 3.14). In both the loved and liked points, the with-hug situation was higher than the without-hug situation.

3.3.2.3 Questionnaire

We asked how impressed the participants were by seven scenes on a 7-point scale (Figure 3.15). Participants were only more impressed by the scene where the boy says "I love you" than the other scenes.



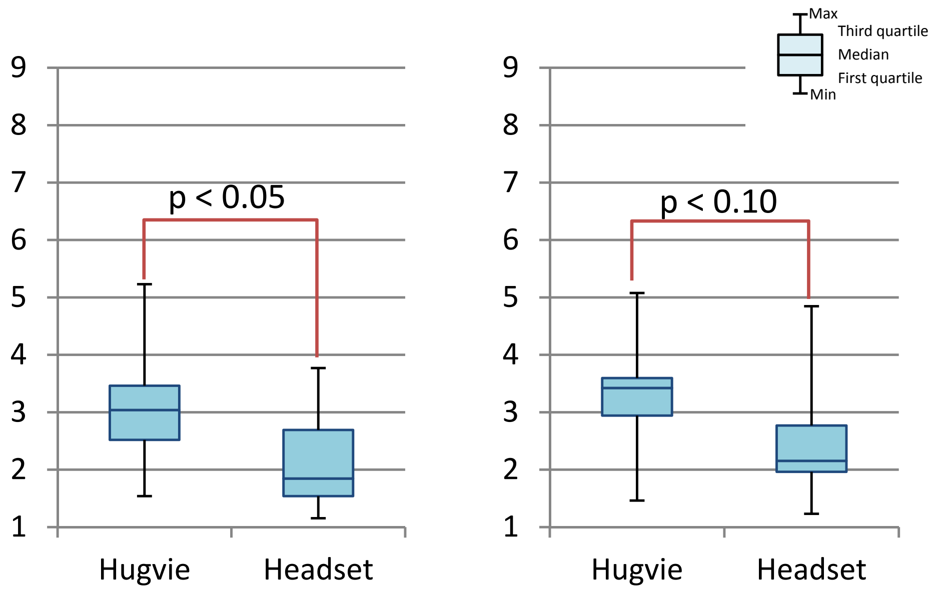
(a) With-hug situation (b) Without-hug situation

Fig. 3.13 Loved and liked points between subjects (vertical axis: average of 9-point scale scores)

Our second questionnaire asked participants to describe their conversation partner. Answers included teacher, doctor, friend, ordinary person, senior, junior, parent, relative, girlfriend, and others (multiple answers allowed); only three in the with-hug situation gave girlfriend as the answer (Figure 3.16). To use the medium at home, the score was significantly higher in the with-hug situation (Table 3.7).

3.3.3 Discussion

We measured the impression toward the movie by asking impression of seven scenes on a 7-point scale (Figure 3.15). Significant difference was found only in the scene where the boy says “I love you” indicating participants using Hugvie were more impressed compared with those using Bluetooth headset (Table 3.6). This scene is where you feel ashamed and embarrassed even if watching by yourself. However, we think such feeling will become stronger if you watch with someone else, especially with someone in close relationship. Since sig-



(a) Total of loved scale points (b) Total of liked scale points

Fig. 3.14 Total points of loved-liked scale (vertical axis: average of 9-point scale scores)

nificant difference was found indicating that the participants get more impressed when using Hugvie, participants might have felt their conversation partner's presence through Hugvie and felt shyness, which result high impression toward the scene. Only three in the with-hug situation answered as a girlfriend when asked participants to describe their conversation partner in the questionnaire (Figure 3.16). This also indicates that the participants imagine their conversation partner as someone in close relationship. Hugging the communication media triggered users to feel and imagine that they are hugging the interlocutor and watching the movie together.

Like Section 3.3.2.1, using Hugvie did not prove to have more active affection toward the interlocutor compared with the headset. However, like Section 3.3.2.2, the feeling of using Hugvie surpassed the headset based on affection expectations. Expecting to be loved means the participants felt affection from their partner even though they are strangers. Here, hugging the communication media triggered users to feel and imagine that they are hugging the interlocutor since they are in a good relationship. As a result, they completed the relations positively.

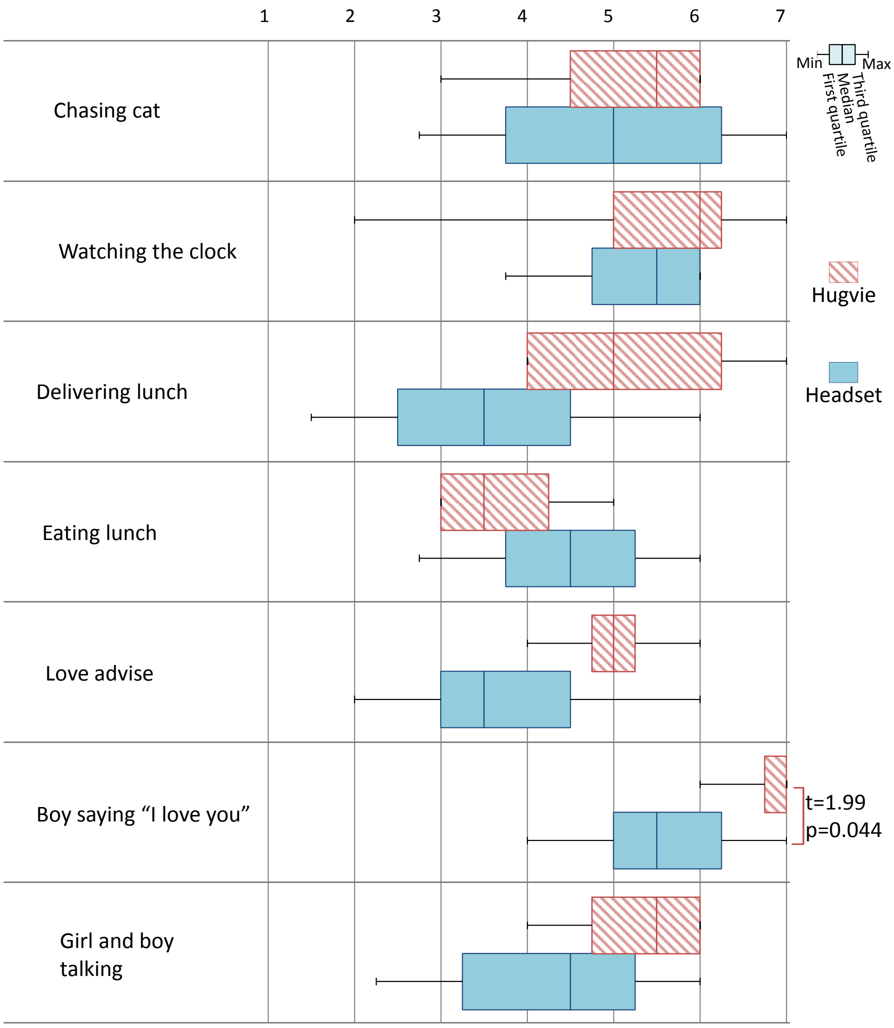
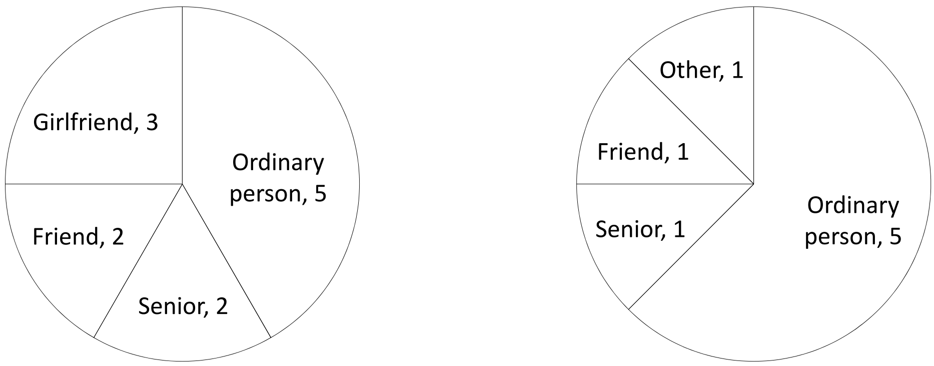


Fig. 3.15 Impression of scenes (vertical axis: average of 7-point scale scores)

The feeling of being loved increased in the loved-liked scale. However, we found no significant differences in the questionnaire results (Table 3.7) between the with-hug and without-hug situations. Since our questionnaire is very naïve, participants may have difficulty admitting the truth to the experimenter. Therefore, even though there was no significant difference in the questionnaires that directly asked about emotions, we found significant differences in the loved-liked scale and in the impressions of the movie, where the participants did not recognize that it was measuring affection.



(a) With-Hug Situation (b) Without-Hug Situation

Fig. 3.16 Whom were you talking to? (multiple answers allowed)

Hugvie is a hugging pillow with a cell phone inserted. It only transmits the voice of the speaker. However, the user has to hug Hugvie in order to communicate with the speaker. As a result, the user imagined that he is hugging the speaker and enhanced speaker's presence. Moreover, the user imagines that he and the speaker are hugging each other because they are in a good relationship and increased the feeling of being loved and liked. Such effect cannot be seen in face-to-face conversation. Here, the lack of information (the presence of speaker) transmitted through Hugvie is enhanced and completed positively by the user's behavior of hug.

The feeling of being loved was inadequate. The average of being loved did not exceed five, which was the medium score, but it showed a significant difference between the situation (Figure 3.13, 3.14), maybe because the participants had difficulty admitting the truth about their mental states. If they knew that the conversation was recorded, their affection toward the interlocutor might decrease; therefore, we arranged 30 to 60 second self-introduction conversations, and only one participant noticed that the female partner's conversation was recorded. To establish a relationship with the interlocutor, people may need longer interaction. Future work will lengthen the interaction time with the female experimenter and determine whether the with-hug situation increases the score of loved scale. We will also subjectively measure stress and heartbeats.

Table 3.7 Questionnaire

Questions	t-value	p-value
Could you hear your partner's voice well?	-1.580	0.931
Did you get nervous while talking with you partner?	-0.318	0.622
Did you get nervous while watching the movie?	1.099	0.146
Were you relaxed while talking with your partner?	0.296	0.386
Were you relaxed while watching the movie?	0.579	0.286
Did you feel that your partner was near while talking?	1.035	0.160
Did you feel that your partner was near while watching the movie?	0.900	0.192
Was the movie boring?	0.389	0.352
Did you feel like talking to your partner who was in the remote place?	-0.875	0.801
Did your partner listen to you?	-0.442	0.667
Did you feel like watching the movie together?	0.347	0.367
Did you expect your partner to call you back?	-0.253	0.596
Do you want to use the medium at home?	3.131	**0.010**
How much affection do you think your partner felt toward you?	0.296	0.386

3.3.4 Summary

Our goal was to make a device that provides an opportunity to establish close relationships. We designed Hugvie to support the relationship by completing the lack of information by hugging it. People who use Hugvie need to hug the device and hear the other's voice as a whisper. In order to see the effectiveness of Hugvie, we conducted a comparison experiment on how people's emotion change by conversation with either a Hugvie or a headset. As a result, we found that the Hugvie enhances the speaker's presence and provides the feeling of being loved.

3.4 Less Modality and Hug for Better Communication

When we dream of an artificial partner for "love", its appearance is the first thing of concern; we desire a very humanlike, beautiful robot. Unfortunately, most of the robots nowadays lack such attribute, such as cute stuffed-bear robot, mobile robot with a monitor, or robots

Fig. 3.17 Geminoid F

with mechanical appearance. Even though, when we get used to such robots, we often feel affectionate and attached to them. However, it is quite rare that we feel such robots as a partner for Eros. People love people. People desire warmth and love from other people. To become a lover, we believe that a robot needs to be very humanlike so that it can substitute a human. One such robot is Geminoid [67]. Geminoid is a teleoperated android made to appear as a human. Among various Geminoids, the female type, Geminoid F, owns a beautiful appearance which at a glance is indistinguishable from a human (Figure 3.17). When faced with Geminoid F for the first time, people often become nervous due to its beauty. Some even say they feel Agape to Geminoid F. However, its limited motions allow people to easily distinguish it from human being.

Another example is sex dolls made by Orient Industry in Japan. They are made to look similar to human in detail. However, the doll's fixed glance and face details strongly remind us that it is an artificial object. One may get used to them. However, to make a robot resembling a human, we have to overcome the effect described as the uncanny valley. Moreover, just overcoming the valley is not enough; we need to get truly close to real human to make a lover robot. This is a very hard task.

At the beginning, we stated that a robot needs to be very detailed to become a target of love. Is this true? For example, when talking to a customer center representative, you may imagine a beautiful lady from her gentle voice and kind attitude. You might even fall in love with her. Here, all you perceive is her voice. You have no clue about her appearance. You cannot feel or touch her. Even though the modalities used for communication are quite limited compared to face-to-face, you imagine of a beautiful lady. It is not what you perceive, but your imagination that drives your affection. Our hypothesis is that such phenomenon occurs due to people's nature to complement lacking information from the limited cues received. Mere voice can make people to have a strong affection toward an unknown person.

In this example, the potential love interest is a real human. Does it make a difference if the voice was synthesized artificially? Probably not. We can utilize this to create an artificial lover. By reducing the numbers of transferred modalities, an opposite approach from making a detailed replica of a human, we can enhance one's affection toward a robot. Moreover, not just transmitting, but by inducing active, unconscious behavior of users, we can increase this effect. In this paper, we will introduce supporting results from our experiments and discuss further applicability of our findings.

3.4.1 Enhancing Human Likeliness

Although the appearance of an android is very real and have an intelligence to communicate, the avatar in the game gave more favorable impression than the android. Why this occurred? The game seems to limit the situation to lovers and add contexts to provide a natural interaction. However, since Geminoid F has a physical existence, we might expect more and the situation cannot be fulfilled to lovers. Previous researches indicate that the appearance of a robot makes people imagine its abilities [17, 39]. Therefore, we might expect more intelligence compared with the avatar. The appearance of the android resulted in negative emotion compared with the avatar with the same intelligence. It seemed to be difficult to recover from the impression we imagined from a real human-like appearance robot. The avatar, which has a virtual presence on the other hand, might have some space to interpret in one's own favor.

Many communication media which transmit rich information about the speaker were invented, and one such robot is Geminoid [67]. However, by making the robot real, the space to interpret in one's own favor decreases, unnaturalness increases, and the impression might be triggered negative. Geminoid does not always provide negative impression. When the model of Geminoid talks through his Geminoid, we might talk to him more friendly or with the strange feeling compared to face-to-face conversation (Figure 1.2). We believe this is because we feel nervous when we meet and talk with the model, and the Geminoid filters and reduces such pressure.

The other media can also impress different impression to others. Compared with the orig-

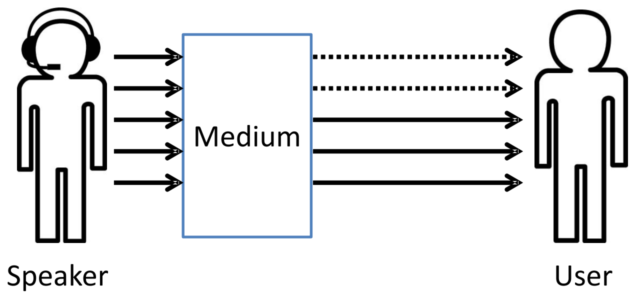


Fig. 3.18 Model of communication medium transmitting information

inal speaker, the speaker's information is missing when one talks through the media (Figure 3.18). We believe the impression changes because there will be space for the interlocutor to imagine about the mediated speaker. We believe such gap of impression would become large as if the number of modalities decreases (Figure 3.19). As we mentioned in the introduction, when talking to a customer center representative, you may imagine of a beautiful lady from her gentle voice and kind attitude. Since the gap is large, the impression would be triggered more positive than Geminoid. Therefore, you might even fall in love with her.

We believe it is people's nature to complement lacking information from the limited cues received. Such lack of information would result in establishing the impression that is different from the original. If we could add some active factors, factors which trigger and input positive impression, we might impress better impression than the original speaker (Figure 3.20). And we think it is effective to add factors to the medium which has less modality and space to imagine for the interlocutors. We will introduce two experiments which support the hypothesis.

3.4.2 Experimental Results

Our hypothesis is that we can trigger and input positive impression by adding active factors to the medium which transmit less modality. We will introduce two experiments and discuss about the hypothesis.

3.4.2.1 Hugvie for Young People

Hugvie (Figure 1.1(b)) is a communication device with a cushion which users have to hug to communicate with others. In the experiment, we focused on the behavior of hug through the media among young people and revealed that using Hugvie enhances the feeling of being

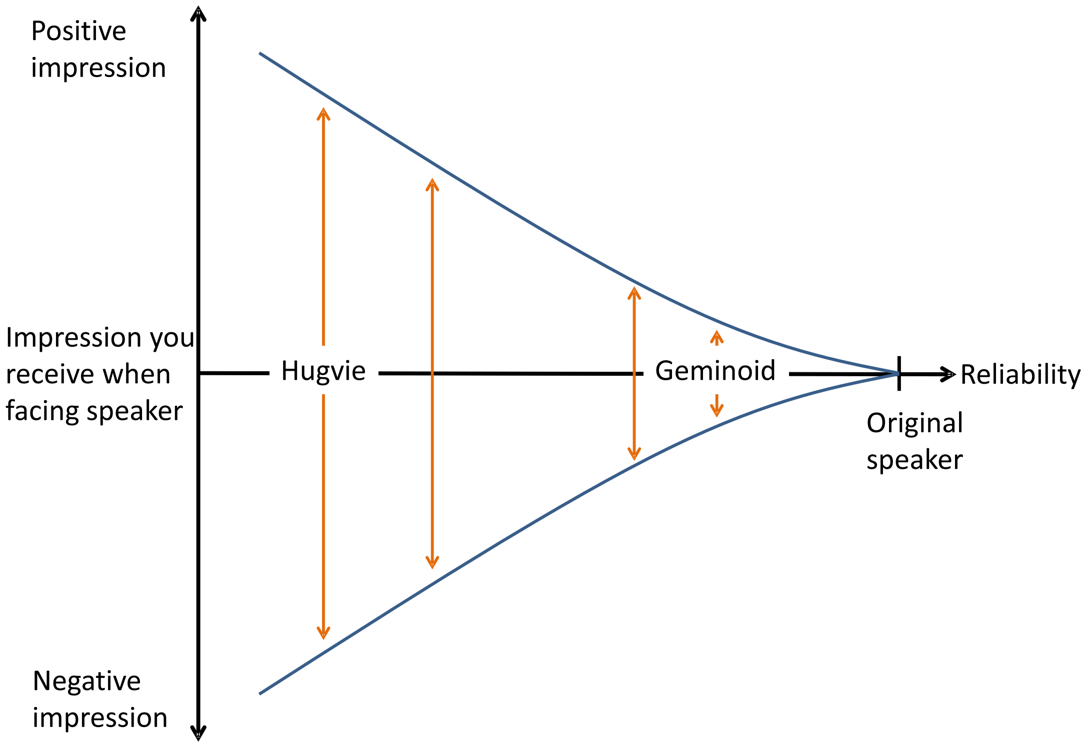


Fig. 3.19 Range of impression and missing information

together and being loved compared to Bluetooth headset [45]. All participants were male university students and told to interact with the other participants, which is a recorded female voice played by experimenter, and watch the movie together. After the interaction, participants answered the questionnaire and the interview.

13 items asked about loved and liked feelings on a 9-point Likert scale, and we compared the total points. As the result, those whose total points of loved items exceeded the liked items were four in the with-hug situation and none for the without-hug situation. We compared the loved and liked points between the media and found significant differences in both loved (t = 1.82, p = 0.046) and liked (t = 1.39, p = 0.095) (Figure 3.14). In both the loved and liked points, the with-hug situation was higher than the without-hug situation.

We asked how impressed the participants were by seven scenes on a 7-point scale. Participants were only more impressed by the scene where the boy says "I love you" than the other scenes indicating that the participants who used Hugvie are more impressed (Table 3.8). This scene is where you feel ashamed and embarrassed even if watching by yourself. However, we think such feeling will become stronger if you watch with someone else, especially with

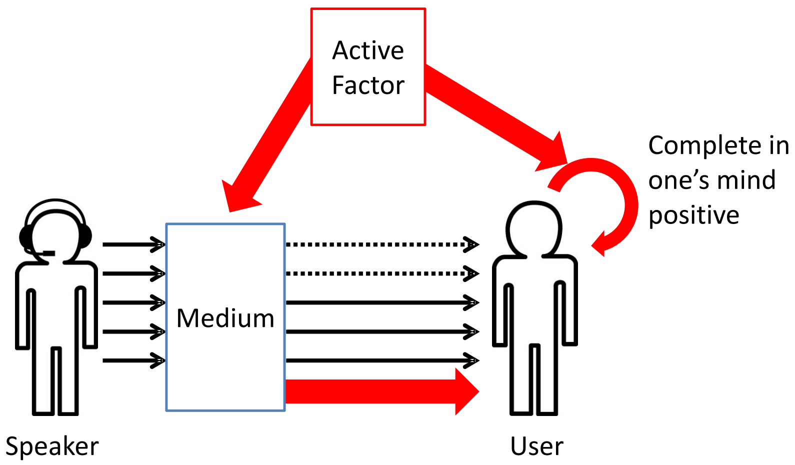


Fig. 3.20 Model of communication medium adding active factor

Table 3.8 Impressed scenes on movie

Scenes in movie	t-value	p-value
Chasing cat	0.193	0.426
Watching the clock	0.228	0.413
Delivering lunch	1.457	0.094
Eating lunch	-0.909	0.803
Love advice	1.394	0.103
Boy saying "love you"	1.989	**0.044**
Girl and boy talking	1.207	0.134

someone in close relationship. Since significant difference was found indicating that the participants get more impressed when using Hugvie, participants might felt their conversation partner's presence through Hugvie and felt shyness, which result in high impression toward the scene.

We believe this behavior of hug triggers the positive impression. Since the user is hugging when using Hugvie, the user would imagine of good relationship with the speaker. The misattribution would occur and the user falls in love with the speaker. Hugvie allows users to hug and provides physical contact. Compared with a headset, immediate contact of Hugvie causes users to hear a voice from it, which may enhance the feeling of being whispered. It can be said that Hugvie limits the speaker's appearance, adds the user's behavior of hug, and stimulates the user's sense of hearing and tactile. Since we rely most of our sense on

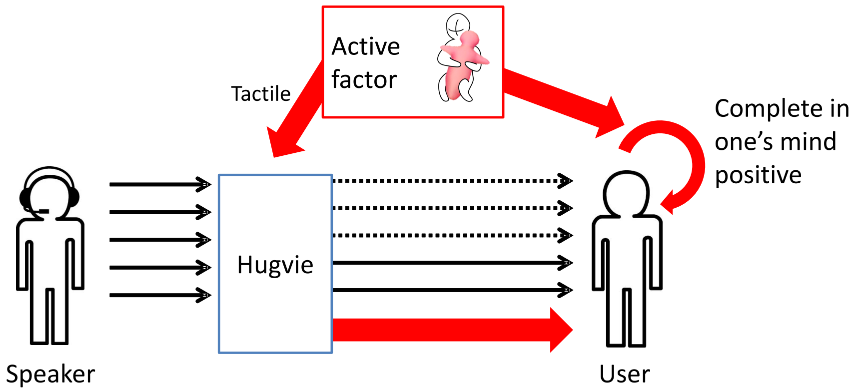


Fig. 3.21 Model of Hugvie

sight, optical illusion may affect the other senses [10, 23, 57, 79]. Limit sight and stimulate other senses which are not mainly used may result in positive impression of a speaker (Figure 3.21).

Mediated conversation limits the amount of information transmitted compared with face-to-face conversation. Especially, Hugvie only transmits speaker's voice. Interlocutor cannot identify speaker's appearance or the behavior. This means that the interlocutor has plenty of space to imagine and complete the speaker's impression (Figure 3.21). Therefore, the impression of the mediated speaker can become more positive or negative than the impression you get when you face the speaker.

When the interlocutor hugged Geminoid to communicate, the user might get to like the speaker. However, we might hesitate to hug for the first time, since the appearance of Geminoid is made to appear as a human. Hugvie, on the other hand, has a plain appearance with a simple modality which reduces the human likeliness mildly. It can be said that the behavior of hug is an active factor which triggers the user to imagine positive impression (Figure 3.21). In the Hugvie experiment, the volume of voice coming out from Hugvie is low, which participants have to hug tightly to hear the voice. Such design to afford users to actively hug might trigger positive impression. If the user imagines himself that he is in love with the speaker, he might fall in love with her.

3.4.2.2 Telenoid for Elderly

This section introduces how elderly with cognitive disorder constructs a relationship with teleoperated robots through a field work of Telenoid R3b (Figure 2.1), the latest version of Telenoid, at elderly facilities. Telenoid is a teleoperated robot with a neutral human-like

Fig. 3.22 Elderly interacting with Telenoid

appearance [69]. Instead of resembling a specific person like Geminoid, Telenoid has a minimalistic human-like appearance that generally resembles a human without any specific personality features. Telenoid has nine independent actuators to synchronize itself with the tele-operator's motion. It can speak, look around, and give a hug. From experiments in Japan and Denmark, we learned that senior citizens are immediately interested in Telenoid from the beginning of their interaction with it [113, 114]. Although Telenoid cannot change face expression, some elderly say it is smiling. Some re-named it and provided hometowns for it. Such imaginary facts came from the minds of the senior citizens.

The elderly have low cognitive functions and dulled senses due to their age. During communication, we believe they have to imagine the information missing from what they received in their minds. Some phenomena support this hypothesis. Sometimes, the elderly with cognitive disorders have conversations with each other. However, they seem to talk about different things. For example, one talks about the weather and the other talks about lunch. During such conversations, they are taking turns and nodding in response to what their partner is saying. Yet they don't seem to hear or understand what the other is saying. However, they are having a conversation. They seem to guess what the other is saying and continue their conversation. They are completing the information that is missing from what they received and guessing about the rest. Since they have lower cognitive functions, they misunderstand what the other is saying.

The elderly, especially those with cognitive disorders, seem to complete the information

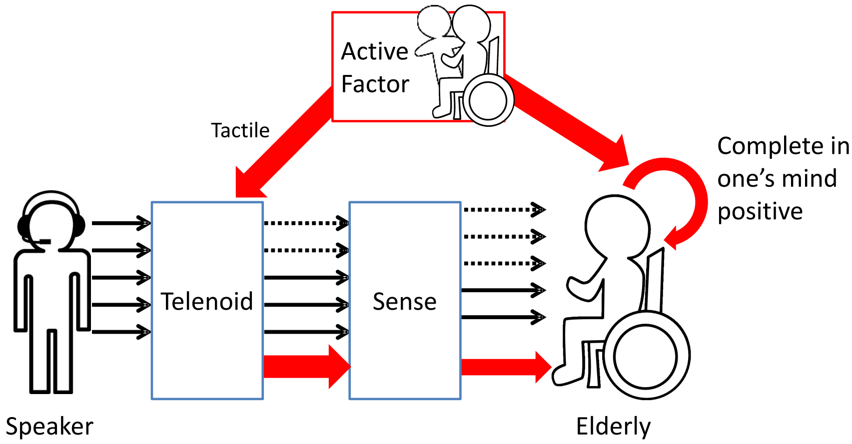


Fig. 3.23 Model of Telenoid

missing in their mind more often than ordinary people. Therefore, such a medium is effective because it positively affects the user imaginations. When a robot is not designed with active factors that elicit positive impressions from the elderly, perhaps they imagine and feel negatively toward the robot. They might be afraid of it. Once they fear it, it is difficult to introduce it to the facilities. A robot that interacts with the elderly needs a design that encourages them to use it. Reliability and comfort are required for a robot that corresponds to the needs of the elderly. By adding factors that create positive impressions (Figure 3.23), the elderly have positive impressions toward the robot.

3.4.3 Summary

We proposed the method and the hypothesis of it as to enhance one's affection by reducing the numbers of transferred modalities. We did not design a medium with a beautiful appearance but a medium which ignores the appearance and let users imagine and complete the appearance. Mere voice can make people to have a strong affection toward an unknown person. We triggered imagination of positive impression by inducing active, unconscious behavior of users.

Reducing the number of modalities can be said to avoid representing a real. In Section 3.4.2.1, Hugvie only transmitted the voice of the speaker. Since it limited factors such as breath or appearance which in some case turns to negative impression, users did not hesitate to hug and communicate. During the experiment, we controlled the conversation and played the recorded voice. However, only one out of twenty one participants noticed that the voice was recorded. It can be said the limited modalities reduced the unnaturalness of the conversation. It is also ignoring the effect described as the uncanny valley [55]. Less modality may avoid the high intelligence we expect from an artificial partner. It can be easily put into autonomous. However, we affected the participant's heart.

The method has a possibility to complete the undeveloped part of the artificial intelligence. We would develop an autonomous robot which allows natural conversation.

The experiment was conducted with a communication medium. However, we believe that the method can be applied to a robot. By reducing the numbers of transferring modalities, we can enhance one's affection toward a robot. Moreover, not just transmitting, but by inducing active, unconscious behavior of users, we can increase this effect.

This method is also useful for the communication media to enhance users to communicate. Many people have trouble getting involved with others and establishing relationships. For example, in Japan, the number of unmarried people between 20 to 39 is increasing (White Papers 2013- Government of Japan). Compared with 30 years ago, the proportion never married increases from 2.60% (1980) to 20.14% (2010) for men and from 4.45% (1980) to 10.61% (2010) for women. Although the number of unmarried people is increasing, they are willing to marry. The rates of those who are willing to marry are 86.3% for men and 89.4% for women, which are both high enough (The National Fertility Survey). This result shows that people are willing to marry but cannot. Nowadays, many events are held to support single people to meet with others. Especially, *Machikon* offers a large number of people, 100 men and 100 women for example, to meet with others. The word *machikon* is an abbreviation of *machi* (town) and *gokon* (mixer), and refers to a large-scale mixer held within towns. Some aggregate data infers that the number of people who have participated in Machikon exceeds two million. People are willing to establish relationships but do not know how. Therefore, we would support such people by using the method of enhancing the impression of users to build a close relationship.

Chapter 4

Applying to Real World Issue: Elderly Care

This chapter focuses on seniors, especially seniors with dementia and uses minimal-design robot as the communication support device to promote communication. Seniors with dementia become depressed and less motivated to talk. However, previous researches indicate that Telenoid is attractive to them and promotes them to talk. We conducted fieldworks to reveal the mechanism of how Telenoid motivates them.

In previous experiments, Telenoid was favorably accepted by seniors with dementia. However, although Telenoid seems to be useful for senior with dementia, it was difficult to conduct experiments at care facilities from the beginning. In Section 4.2, we explain problems and solutions of introducing robots to elderly facilities for the first time. When developing new equipment to introduce to the facility, we have to consider what is needed by the staff and the facility. When we tried to introduce Telenoid into one facility, we placed Telenoid to the facility so it can be used anytime but caregivers never used it. In order to introduce robot and be useful, we have to consider about seniors with dementia and also the staff at the facility.

In Section 4.3, we conducted a long-term experiment revealing how effective when using Telenoid to communicate instead of face-to-face. As a result, we found that two participants with moderate Alzheimer's disease showed a favorable impression when talking with Telenoid than face-to-face conversation. During the interaction with Telenoid, they treated Telenoid like a child or baby. Such behaviors come from imaging Telenoid as a child since they are hugging a small human-like robot. And the imagined image resulted better than the original person talking face-to-face. During the interaction, the subject actively hugs and touches which may result to imagine positive impression. The other participant which has severe Alzheimer's disease had difficulty communicating with both Telenoid and face-to-face. However, we found that she conducted physical interaction and gestures to communicate.

Section 4.4 examines how imagination works when seniors with dementia are having a conversation with Telenoid. In previous studies, we found that many seniors with dementia are strongly motivated to have a conversation with Telenoid. Our hypothesis on why seniors are so motivated is that 1) due to the low sensing and cognitive function of senior with dementia, they own a strong tendency to complement missing information, 2) only limited amount of information is transmitted due to the "minimalistic design" of the Telenoid, and 3) the hugging act required to use Telenoid induces a positive bias in the complement process. Based on this hypothesis, we prepared a mock-up of the Telenoid which owns identical appearance and weight but lacking motor abilities. In this paper, we report results from our case study where one senior with dementia had several interactions with the mock-up. Based on the results, we discuss the role of imagination in the cognitive process of seniors with dementia.

By restricting the information to be transmitted, we can encourage the user to imagine and complete, however, the amount and quality of information transmitted matters to complete positively or negatively. In experiments using the mock-up of Telenoid in Section 4.4, in the case of mock-up, when no speech is produced, the interaction was performed, but the amount of utterance of the user decreased compared to the normal Telenoid. This was because the mock-up said nothing which causes the participant to imagine a baby. The information can be limited to enhance imagination, but there need verbal information or some other information which allows users to imagine someone who can talk, in order to motivate communication. We focused on the behavior of hug as an element of imagining positive impression, other factors such as quality of voice and gesture can be considered in future works. We would like to further investigate what kinds of elements will positively affect users.

In Section 4.5, we developed a simple automatic dialogue system focused on the characteristics of senior with dementia imagining and completing the lack of information while interacting. Since elderly people with dementia often have unclear utterance, the system focused on nonverbal information to communicate. We developed the system which estimates the emotional state from the gesture and expression of the partner, and we also prepared an internal state of the system and expressed it by the robot. As a result, the system was able to recognize when the participants were not paying attention, and they recognize that the robot is happy when the robot is expressing a happy state.

Senior with dementia actively hugged or touched when interacting with Telenoid. It is thought that such physical interaction leads to favorable imagination and reaction. Such interaction is possible because of the physical presence of the robot.

4.1 Related Works

Recently some attempts have started using information technologies and robots to increase the opportunities for seniors to communicate. One example is the Mobile Robotic Telepresence (MRP) system which is a video conferencing system mounted on a mobile robotic base. It allows users to telecommunicate with residents from remote locations, and several researches have been carried out with it [3, 40, 71]. Kuwahara *et al.* developed networked reminiscence therapy which effectively increases the self-esteem of and reduces the behavioral disturbances in seniors with dementia [42]. Their system combines IP video phones with a photo- and video-sharing facility. In their experimental results, elderly with dementia communicated with therapists by videophone, and networked reminiscence sessions were generally as successful for individuals with dementia as face-to-face reminiscence sessions. We also tried to introduce tablets and video chat to the residents who showed interested in such new devices. However, they soon returned them to us. Although they seemed willing to directly communicate with others, they were discouraged from using such communication tools as phones or video chat. We believe that to increase the opportunities for seniors to communicate, it is important to not just introduce a communication device but also to motivate them to use it.

Perhaps the most famous elderly care companion robot is Paro, a baby seal robot designed for therapy [108]. It has sensors on its body and reacts with sound and several actuators. Its cute appearance and behavior stimulates the interest of the elderly. Compared to the resident dog, the residents who interacted with Paro significantly felt less loneliness, and they also talked to it and touched it more than the resident dog [77]. From seniors with mild/moderate dementia, Paro evokes natural expressions more frequently than stuffed animals and is likely to increase the willingness of the staff members to communicate and work with senior with dementia [96]. However, since it is not designed for verbal communication, seniors talk to Paro which reacts but cannot have a conversation.

To introduce a robot to elderly care houses, caregivers must constantly use it and residents must be discouraged from losing interest in it. Manuals for use and introduction in care facilities exist for Paro [107], and Kanagawa Prefecture in Japan also provides support for introducing robots into care facilities. These allow users to properly employ such robots; otherwise, users will lose interest and stop using them. Tanaka *et al.* updated the behavior of a robot called QRIO during trials to maintain the interest of a classroom of toddlers. Otherwise, children seldom reacted to it [97]. Users might lose interest in robot because of low intelligence, or few variety of reaction in the robot. Sabelli *et al.* placed a robot called Robovie2 which was remotely controlled by an operator, in an elderly care center for 3.5 months [82]. Through the ethnographic study, they found that the robot was accepted in the community. However, they provided only ethnographical descriptions and performed no statistical data analysis. As such, although there have been trials to use robots in care facilities for rather long duration, study with objective measurements have been missing and effective methodologies for utilizing robots while keeping people's interested have been unclear.

From experiments of Telenoid in Japan and Denmark, we found that seniors with dementia often showed strong attachment to and liked to communicate with Telenoid [112]. Although it is difficult to communicate with seniors with dementia, school children were able to communicate with the residents without training by using Telenoid [114]. We found that Telenoid could motivates seniors with dementia to have conversation with others, while making people talking through Telenoid to be much relaxed compared to face-to-face. However, the quality of the conversation and how third person such as caregivers observing the interaction feels are unrevealed. Also, how people's response to Telenoid changes in longer term is not clear.

In Section 4.3, we described a long-term fieldwork conducted in a group home (a community-based care facility where mild/moderate demented seniors live together) and compared face-to-face communication with communication mediated through Telenoid. We evaluated the quality of the conversation by questionnaire. The questionnaire was answered by the speaker and the observer to reveal the effect of third person. We discussed the possibilities of using Telenoid as a tool to support long-term communication between people and elderly individuals.

4.2 Issues on Using Elderly Care Support Robots

In 2013, approximately a quarter of the population in Japan was senior aged over 65 [6]. Approximately 4.62 million seniors were suffering from dementia and about 4 million were suffering from mild cognitive impairment (MCI). The number of seniors who needs care has been increasing rapidly and the burdens on their families and caregivers have been increasing accordingly.

Equipment for nursing care, such as lifting machines and communication support robots, have been developed to support care. However, it is difficult for caregivers or residents to use such new equipment because they often tend to refuse unfamiliar equipment. In the context of such concerns, we first need to fully consider how new equipment should be introduced to care facilities. For example, Sugihara *et al.* [90] introduced a video monitoring system, which can monitor the blind spots in a care facility. However, it reported that security and the loss of privacy were concerned by caregivers. Also our interview to the manager of one care facility in Japan revealed that some residents did not feel like taking a bath in the nursing care. This is because Japanese people usually do not sit on a bathtub and like to lie on it. Also, some were scared of the machine which automatically assists in taking a bath. Such equipment is useful but there remain many concerns for developers, caregivers, and residents to care. Meanwhile, we had developed a teleoperated robot Telenoid for communication support, and then placed it in a facility so that caregivers could use it anytime. However, contrary to our expectation, it had never been used after once the robot was stored in a storage room. This means that it is also important for caregivers to be motivated in order to feel free to use such new devices.

Therefore, developers are also required to well consider how such new equipment can be introduced so that caregivers and residents can feel free to use. In this paper, we studied a case that Telenoid was introduced to three care facilities and discussed the problems and the solutions in introducing new equipment. Section 4.2.1 explained specification of Telenoid and previous field work, and described the issues. We discussed possible solutions to the issue in Section 4.2.2. Section 4.2.3 described the way to introduce new equipment, and the conclusion was in Section 4.2.4.

4.2.1 Telenoid

Telenoid (Figure 4.1) has a human-like appearance and is operated by a remote person. It is covered with a soft skin made by silicon or soft vinyl. The head moves synchronized to the movement of the head of the operator, and when the operator speaks, Telenoid moves its mouth synchronized to the operator's utterances and speaks. It can move its arms by the operator pressing a button on operating PC. The appearance of Telenoid is neutral and has no gender. Telenoid can be seen as a male or a female, and an adult or a child to be easily recognized by a conversation partner to imagine the operator. The conversation partner can

Fig. 4.1 Telenoid R3b

feel the remote operator's presence while interacting with Telenoid. Based on the research of Geminoid (a humanoid robot resembling a real person), Telenoid is designed to have a minimum appearance and function to feel a human presence during the conversation.

From field work in Japan and Denmark, we found that seniors showed strong interest from the beginning of the interactions with Telenoid. Some seniors hesitated to let it go [69, 111, 113]. It is known that Telenoid makes conversation lively for seniors with mild to moderate dementia, and enables to have nonverbal communication with a senior with severe dementia [44].

This paper studied a case that Telenoid was introduced to two care facilities and discussed the problems and the possible solutions in the case that new equipment for care was introduced to the facilities. The facility we introduced Telenoid (Facility A) was a special nursing home for the elderly with eight to ten residents in each unit, and each unit had a public space and a private room for each resident. The maximum capacity was 50 persons, and at least one caregiver was there for two residents. First, we discussed a case that Telenoid was introduced to one unit in Facility A.

4.2.1.1 Reactions from caregivers

When we first brought Telenoid to Facility A, staffs and caregivers were looking at Telenoid skeptically. From its unique appearance, their first comment was "scary" or "Why can't it be made cuter?", wondering if it was really useful. We explained the concept of Telenoid and how it works by showing a movie of elderly people interacting with Telenoid, and staffs and caregivers agreed that Telenoid is useful. However, they claimed that such a robot would need human resources and it would take a time for them to be familiar and to handle; they were busy enough to maintain their daily routine and had no time to try new devices.

Although we placed Telenoid to the facility so it could be used anytime for a trial, caregivers never used it, and Telenoid was left alone. One resident told to the caregiver that she felt sorry for Telenoid being there alone. As a result, Telenoid was stored in the storeroom so no resident would notice it.

4.2.1.2 Reactions from residents

Since Telenoid cannot move by itself from the stand it was placed on, someone has to carry and give it to the resident at first. When caregivers used Telenoid, they did not know how to handle it and they felt awkward of using it. Some caregivers were hesitated to use it since it is a precision robot and they thought they might break it. One caregiver passed Telenoid to a resident without saying anything, and the resident was surprised and said, "No, thank you. I am OK" and refused to interact with Telenoid.

4.2.1.3 Reactions from operators

In Facility A, there are volunteers who listen to residents' talk regularly twice a month. They operated Telenoid when they were in the facility. We also conducted a teleoperating from the building of the volunteer center.

Most of the volunteer staffs were housewives or seniors, and had little experience of using PCs and other electronic devices. Therefore they hesitated to operate such devices. In addition, since most of the operators gazed at PC screens and talked at the beginning, they rarely moved their head. Consequently Telenoid did not move its head, either. Most of the people had never experienced interacting with Telenoid, so they did not seem to have any confidence all though conversations in teleoperating.

4.2.1.4 Problems

One of the reasons why such equipment did not go well at the beginning is that caregivers had no concrete image or vision of how to use it. Firstly, caregivers are busy with daily tasks, and it is extremely hard to take a time to do other things. In the facilities we conducted a fieldwork, caregivers suffered from not having enough time to communicate with the residents. It is said that less social connections increase the risk of becoming dementia [14] and communication is important to understand the conditions of seniors with dementia. Why do caregivers have less time? Caregivers have daily tasks such as preparing meals and supporting bath and also have to manage BPSD such as wandering and depression. Such BPSD varies on each resident, day, and time. Caregivers always need to pay close attention to residents in order to manage BPSD. Caregivers have a lot of duty but most of the residents have nothing to do and just watch TV or sleep. It seems as if their BPSD happened more often since residents had nothing to do and communicated less with others.

Meanwhile, in the other special nursing home for the elderly (Facility B) where we introduced Telenoid, training for caregivers and staff meetings were held frequently, and caregivers communicated with residents more often. The residents were calm and seemed like their BPSD appeared less, which brought caregivers more time to take for other care. In Facility it B seemed like BPSD were decreasing by communicating with residents more often even when they were busy. It is difficult to communicate with residents who became aggressive or depressed by BPSD. Therefore, we think Telenoid is useful because it is designed to encourage residents to communicate. Caregivers may need extra time to use this, however, it may provide opportunities for residents to communicate, which could decrease BPSD.

In order to introduce Telenoid and be used by caregivers, it is necessary for them to focus on the current problem that they rarely communicate with residents. Since the daily work is busy, caregivers have no time to try new devices. However, we believe that they need to realize that such new devices may reduce daily work. The problem of not having enough time might come from not realizing the problem they really have to address for residents and from being less motivated to think about it. If staffs or caregivers realize the problem and are motivated to solve it, we believe that they would try new equipment by themselves.

There will be another problem after caregivers become motivated to use new equipment. That is, the users of new equipment are unfamiliar with it and have to get used to it. If the equipment is used inappropriately, it may fail to support care. Even if the new equipment is useful, the way to use is more important. An interactive robot “Paro”, a baby seal robot that supports seniors with dementia, has a manual which explain methods and the way to use for users [107]. The manual includes how to hand Paro to seniors and the way to handle, for example, it should be treated like a living animal when the seniors with dementia are looking at it. The manual notes that it is important to take a break and prevent residents to get bored by using it for an extended period of time. Staffs or caregivers who use the new equipment have to understand the way to use well. And in order to understand the new equipment, it is necessary to practice and get used to it.

It is also necessary for developers to design the equipment easier for caregivers to use. Therefore users' (caregivers') feedback, evaluation, and discussion after several trials are essential for developers. Each trial needs to be recorded for evaluation. By accumulating such trials, caregivers can also understand more whether the equipment is useful or not and will be able to plan how to use it next.

When introducing the robot to a facility, the following problems can be concerned.

- Users to understand what the robot is.
- Users to understand the importance of the way to use and get used to the robot.
- Developers to design the robot for daily use.
- Record trials and periodically evaluate and discuss them.

From the next section, we will discuss and introduce how to solve these concerns.

4.2.2 Method

4.2.2.1 Importance of Explanation

When introducing new equipment, caregivers do not know how useful it is and might be not motivated to use it. It happened when introducing Telenoid, too. Since caregivers could not realize that it was useful, they were less motivated and hesitated to use it. The reason was that caregivers did not understand what Telenoid was and how effective it was. Therefore we prepared a guidance manual for Telenoid users. The manual indicates the importance of listing up current problems and thinking about the solutions, and it explains an example of how Telenoid can solve the problems. The manual also includes case studies of using Telenoid, such as what kind of conversation can be done through Telenoid, so caregivers can easily imagine how it can be used.

In addition, we conducted a brief meeting for caregivers and staffs and explained about Telenoid so they could understand well about it. Participants experienced operating Telenoid and they learned by interacting with it. The details of Telenoid and case studies were explained in the meeting. We asked about the problems caregivers and staffs had and discussed how Telenoid could be used to solve them. We then lectured how to setup and use it by themselves afterwards.

By actually talking with caregivers, ideas came from them. For example, Telenoid might be operated by staffs in the office when they have a time. By considering opinions came out in the meetings, the interface and systems of Telenoid have improved.

In Facility A, by making a manual and holding meetings, caregivers understood well about Telenoid, and they seemed to be motivated and discussed the problems by themselves. In Facility B, we demonstrated and explained Telenoid for about an hour during the leader meeting where a representative of each unit gathered. At that time, we distributed the manual, which helped many caregivers and staffs be able to understand Telenoid, and there were opinions from several caregivers that Telenoid might be good for some residents.

4.2.2.2 Trials

We cannot expect the residents' reactions to new equipment beforehand. Even if the equipment worked effectively in previous trials, we cannot guarantee that it is also effective for other residents. It also depends on how it is used; it may result in negative effect in some cases. For instance, some residents can think Telenoid is alive even if it is turned off, then caregivers should treat it like a real baby. In this case, they have to hide it when it is not used from residents so that the residents do not get worried about it.

Since the new equipment is unfamiliar for caregivers, they might get confused about how to use it. Furthermore, Telenoid tends to be recognized as precision equipment, and caregivers might get nervous to handle it. To get used to Telenoid, we prepared a mock-up of Telenoid. The mock-up is covered with the same skin of Telenoid, and the inside is filled with clay and cushion. The appearance, weight, and center of gravity are the same as Telenoid. It does not include precision equipment, so it can be used roughly and placed to the facility for a long term. Some residents who loved to interact with Telenoid also showed positive reactions to the mock-up. The mock-up can also be useful for caregivers to get used to it. By showing it to residents and looking at their joyful reactions, caregivers can actually imagine the scenes where they use it. In addition, we also used the mock-up instead when we explain and introduce Telenoid, and practice using it.

We attempted to place the mock-up for about a week before using the actual Telenoid. The mock-up was easily handled by caregivers. This attempt was effective for us to determine which residents would use Telenoid. Since a technical person was not required when using the mock-up, we were able to place it for a long term. Not only caregivers but also staffs of Facility A had opportunities to touch and interact with the mock-up and people in the facility were able to know about Telenoid.

4.2.2.3 Improvement

We also improved the function of Telenoid for caregivers to use it more often. We simplified the setup of Telenoid and placed the mock-up, so caregivers could feel free to use. Current Telenoid can be automatically connected to the network and be ready to use just by turning on power. We also created a carrying case to store Telenoid, which enables us to prepare it in a short time. In addition, we prepared an equipment manual for the setup and the troubleshooting. By using the manual, a group member of three graduate students who had never used Telenoid before was able to setup Telenoid in 37 minutes, and the remaining four groups who had watched the setup of the first group were able to prepare it in the average of 16.5 minutes, including the shortest time of 6 minutes.

By placing the mock-up in the facilities, caregivers were able to imagine when to use it. In Facility B, there was one resident who became offensive to other residents and caregivers, but she interacted with Telenoid kindly. Caregivers then gave Telenoid to the resident when she was in a bad mood. The mock-up was also used to wake her up. Such increased numbers to use indicate that caregivers understood the effect of Telenoid and were motivated to use it.

4.2.2.4 Evaluation and Discussion

According to the nursing care records in both Facilities A and B, the caregivers in Facility B seemed to look back the records more often, for example, in shift changes. By recording the daily care and detail status of residents, it becomes possible for us to discuss a better care. It is also important to record trials and look back on the time when we introduced the new equipment. After the trials, both caregivers and developers should look back and discuss what was good or not for the next trial plans. Furthermore, if the new trial works effectively, which promises to enhance caregiver's motivation, and accordingly they start to imagine not only how to use it, but also what they can do for better care. As a result of mutual discussion between both caregivers and developers we believe that we can find the way to use and improve the performance towards better care.

4.2.3 How to introduce

The new equipment requires be examined and considered carefully to introduce to facilities. The developers of the equipment are mostly not the ones who work at care facilities. Therefore developers are required to understand what caregivers are suffering from and need.

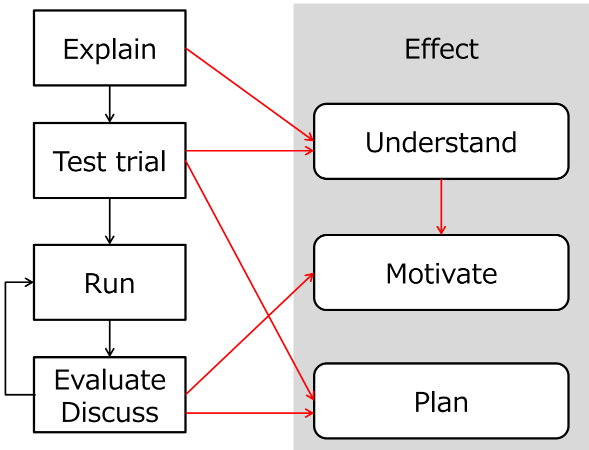


Fig. 4.2 Overview of Introduction Procedures

Since caregivers are the main user, developers are required to carefully explain the way to use and provide opportunities for them to understand. Based on the problems and solutions in introducing Telenoid as mentioned above, we renewed a flow chart (Figure 4.2). We have noticed that the developers' work was not just bringing it to the facility for caregivers to use it. One of the problems that we faced when introducing Telenoid to Facility A was that caregivers were not motivated to use it. This can generally be a problem when introducing new equipment. To introduce and test new equipment, it was important for developers to consider the motivation of caregivers, too.

This is because motivated caregivers can use the new equipment by themselves. At first, developers need to get caregivers to realize the current problems they have and get them to understand the needs of the equipment. We therefore held a meeting to explain and demonstrate Telenoid. We also arranged another time to discuss with caregivers so caregivers could think back on current care and realize the problems they have. After the meeting, we believe that caregivers can imagine how to use the equipment and can be motivated to use it.

Next, caregivers need to get used to the equipment. Especially before using precision equipment, it is better to practice with the mock-up first to simulate the situation using the equipment so that caregivers can then easily imagine how to use it, and they might imagine which resident is suitable to use. If caregivers were able to handle, they can use it more often and figure out the way to use by themselves.

After using the equipment, it is necessary to look back, evaluate, and discuss. To date, the purposes of most of the new equipment are easy to understand. For example, nursing care bath is to support taking a bath. However, even such simple machines could be refused when they are introduced suddenly. Telenoid is complicated to handle, so caregivers have to fully understand the way to use. It should be noted that sometimes the effect may go negative if the way to use is wrong. It is important for all of us to share how Telenoid was used and to discuss the previous trials. By sharing case studies and understanding the possible effects, caregivers will get motivated and may figure out effective solutions for the next trials.

4.2.4 Summary

In this paper, we indicated that the new equipment could be a burden for nursing care staffs. We also explained issues and possible solutions towards introducing Telenoid to care facilities and discussed the procedures of introducing such new equipment: developers are required to get caregivers to understand the way to use and to be motivated to use; and evaluation and discussion after several trials are also important because those efforts may lead to better care. For future work, we are planning to arrange training courses to practically use Telenoid.

4.3 Long-Term Fieldwork

This work presents a case study on fieldwork in a group home for the elderly with dementia using a teleoperated robot. We developed a robot called Telenoid to provide communication support for seniors (Figure 2.1). Telenoid is a teleoperated robot covered with soft vinyl that can transmit a remote operator's physical movements and voice. Telenoid users can physically interact (hug and touch) with the robot while communicating with an operator who can communicate from a remote place through the Internet. From experiments in Japan and Denmark, we found that seniors quickly became fond of interaction with Telenoid, and seniors with dementia also liked it [112]. However, the effects of using it and how communication differs when talking through Telenoid compared to face-to-face communication are not clear.

In this paper, we describe a long-term fieldwork conducted in a group home (a community-based care facility where mild/moderate demented seniors live together) and compared face-to-face communication with communication mediated through Telenoid. We discuss the possibilities of using Telenoid as a tool to support long-term communication between people and elderly individuals.

4.3.0.1 Background

The population of senior citizens is rapidly increasing worldwide. In Japan, more than a quarter of the population is already over 65 [6]. The number of elderly with dementia has reached 4.6 million, and an additional 4 million people probably suffer from mild cognitive impairment (MCI). The Japanese Ministry of Health, Labour and Welfare estimates that the social cost of elderly with dementia was 14.5 trillion yen (approximately 118 billion US dollars) in 2014.

This trend, which is not specific to Japan, can also be seen globally [105]. In the more developed regions, populations aged 60 or over are expected to increase by 45% from 287 million in 2013 to 417 million in 2050. In the less developed regions, populations aged 60 or over are currently increasing even faster, and the numbers are expected to rise from 554 million in 2013 to 1.6 billion in 2050. With an increase of senior citizens, the number of people suffering from dementia is also likely to rise and will impose a severe social cost.

As societies continue to age, the number of seniors living alone will increase. Such changes limit opportunities to communicate with others and weaken their connection to society. Such limited society connections increase the risk of dementia [14]. Furthermore, as the degrees of dementia progress, seniors become more withdrawn and experience more difficulty communicating with others including caregivers.

The most common cause of dementia is Alzheimer's disease (AD), which is perhaps responsible for up to 60-70% of all dementia cases [110]. AD is a chronic progressive neurodegenerative disorder characterized by the following symptoms: memory loss, language difficulty, executive dysfunction, psychiatric symptoms, such behavioral disturbances as depression, hallucinations, delusions, agitation, and difficulty performing daily living activities [5]. Seniors with AD sometimes reject care and become depressed or belligerent as a result of the behavioral and psychological symptoms of dementia (BPSD). They forget what they have done or said in the short term due to memory impairment. Understanding both the physical and mental conditions of seniors is important for taking care of them. However, accurately determining their mental conditions is difficult since identifying clues that might elucidate their emotional states when they are depressed are complicated. Therefore, it is important for caregivers to motivate seniors with AD to communicate to cope with BPSD and to suppress progress of dementia.

At the same time, the aging of society is exacerbating caregiver shortages. In fact, the lack of caregivers and their job turnover is already severe in both developed and developing countries [38]. According to a survey by a careworker foundation in Japan, 59.3% of caregivers feel overworked due to the actual lack of caregivers whose annual turnover rate has reached 16.5% [7]. Although the number of seniors who need care is increasing, the number of people who work as caregivers is decreasing, due to low wages (61.3%) and physically/mentally hard work (49.3%). Improving caregivers' working lives and motivating them is crucial [49].

The lack of caregivers makes caregivers busy and decreases opportunities for caregivers to communicate with residents. If seniors suffer from severe AD, they rarely respond to care. As a result, caregivers have difficulty communicating with their charges and become discouraged. To maintain their motivation, caregivers need skills and adequate time to properly communicate with seniors with dementia. However, this requires experience and training, and it is especially difficult for new/inexperienced caregivers who are often too busy to take time to communicate with their residents.

In Japan, there are volunteers who visit care facilities periodically to have conversation with residents. For smooth communication with the residents with AD, the volunteers need to be trained. Even though they provide opportunities for seniors to have conversation, they cannot attend the facilities every day. The volunteers usually belong to nonprofit organizations and can only visit facilities near their houses occasionally. In the facility at which we conducted our experiment, volunteers only visit once or twice a month and talk with just a limited number of residents. Although there are telephones in houses or care facilities, residents with AD rarely use it to have conversation with others. This may be partially due to their weakened hearing ability by aging but also due to their lack of motivation to speak with others. With the progress of AD, one feels difficulty in composing and understanding dialogue properly. By recognizing the decline in their ability, residents with AD quickly lose their motivation to speak with others.

In this paper, we introduce a teleoperated robot Telenoid, which can be teleoperated from remote place. By using Telenoid, seniors living alone or in nursing homes will have more opportunities to communicate with their family or volunteers. The small and soft body of Telenoid allows people to hold it while having conversation through it, allowing one to have communication with multiple modalities including visual and tactile sensations besides dialogue. Moreover, Telenoid's child-like appearance might attract residents and motivates them to communicate. If Telenoid can motivate residents to communicate, they will become more active or emotional, and caregivers will be able to understand their physical and mental conditions easier.

4.3.1 Telenoid and Face-to-face Communication

4.3.1.1 Participants and Ethics Statement

Three female residents (from 85 to 96 years old) of a senior group home participated in this study. They were all clinically diagnosed as AD. Informed consent was obtained from the group home manager, the doctor in charge, and the participant families. This experiment was approved by the Human Ethics Committee of the Graduate School of Human Sciences, Osaka University (No. 26-60) and the Ethics Committee of the Advanced Telecommunications Research Institute International (No. 14-602-3).

4.3.1.2 Procedure

The experiments were conducted once or twice a week for three months in a group home for seniors with dementia in Osaka, Japan. The dates and times of the trials were adjusted based on the conditions of the participants and the convenience of the group home. All conversations were exchanged in a public space, either in the dining room or the TV room.

Participants spoke with a person (henceforth *speaker*) in a face-to-face condition (Face condition) and a Telenoid-mediated condition (Telenoid condition). The conditions were randomly ordered and the duration of the conversations was limited to 15 minutes each. The conversations were suspended when the participant was not feeling well or was unwilling to talk. An *observer* monitored the interaction between the participant and the speaker in both conditions. After both conditions were conducted, the speaker and the observer answered questionnaires. We recruited five university students who major in gerontology as evaluators. None of the evaluators had experience of using robots. They played the speaker and observer roles in turn. We asked them to make evaluation in the quality of conversation and made no further specific instructions.

In the Telenoid condition, the speakers controlled a Telenoid R3b (Figure 2.1) to communicate with the elderly participants by a teleoperation system from a remote location (Figure 2.2). Another experimenter first carried Telenoid and sat in front of the participant. During the conversation, the experimenter gave Telenoid to the participant, and if the participant did not refuse it, the participant held it and continued the conversation. When participants held Telenoid, they put it on their laps and sometimes leaned it against a desk. Telenoid has six independent actuators (jaw movement, yaw, pitch, and roll movement for its neck and horizontal movements for each arm) that allow it to synchronize motion with the speaker. The speaker's head motion is captured by sensors (3-axis accelerometer and

3-axis magnetometer) embedded in a headset and transmitted to the robot. Speech-driven lip motion generation, which creates lip motions from the speaker's vocal information, is used to control Telenoid's jaw movement [31].

4.3.1.3 Evaluation

■4.3.1.3.1 Diagnosis of Dementia The caregivers of the group home answered the following cognitive function tests before and after the experiment. We used these tests to measure the cognitive function of the participants and AD's progress during the experiment.

1. Mini-Mental State Examination (MMSE): 30-point questionnaire that is used extensively in clinical and research settings to measure cognitive impairment [72]. Any score greater than or equal to 27 points (out of 30) indicates normal cognition. Scores below indicate severe (≤ 9 points), moderate (10-18 points), or mild (19-24 points) cognitive impairment [60].
2. Quality of life questionnaire for dementia (QOL-D): 31 items grouped into six response sets to measure six domains of health-related QOL [100].
3. Dementia Behavior Disturbance Scale (DBD): 28 items, measured by the frequency of BPSD on a 5-point scale [54].
4. Japanese version of the Neuropsychiatric Inventory (NPI-NH): measures 12 symptoms of neuropsychiatric disturbances [25].
5. Barthel Index (BI): measures performances of activities of daily living (ADL) by ten items [85]. A total BI score of 0-20 suggests complete dependence, 21-60 indicates severe dependence, 61-90 indicates moderate dependence, and 91-99 indicates slight dependence.
6. Vitality Index (VTI): measures vitality related to ADL in elderly patients with dementia by five subscales [101].

■4.3.1.3.2 Questionnaire The speaker and the observer filled out the following questionnaire, where each item was rated on a 5-point scale:

- Q1 Smoothness of conversation (rough-smooth)
- Q2 Amount of conversation (poor-rich)
- Q3 Quality of conversation (low-high)
- Q4 Impression of participant (gloomy-cheerful)

Q5 Emotional state of speaker (nervous-relaxed)
Q6 Emotional expression of speaker (poor-rich)
Q7 Understanding participant (not understood-understood)

Items in the questionnaire were listed to measure the quality of the conversation. Q1, 2, 3 measures the quality of the conversation more quantitative, and Q4, 5, 6, 7 measures the impression of the residents and speaker more qualitative. We included these items to measure whether residents were motivated to communicate, and to measure the impression of observer observing the conversation.

Hereafter, we denote a speaker's response to Qn as Sp_Qn and an observer's response to Qn as Ob_Qn. The questionnaire scores were compared between the Telenoid and Face conditions within subjects by paired t-tests to reveal the effect of using Telenoid. We compared the scores of the first and last five trials in each condition (by Student's t-test when homoscedasticity was confirmed and Welch's t-test when unconfirmed) to determine any long-term effects.

■4.3.1.3.3 Video Analysis A surveillance camera in each room (the dining and TV rooms) and one mobile camera were used to record the interactions. From the video recordings, we counted the number of times that the participants used body gestures and made physical contact. Due to limited views, we counted only the number of clear upper body gestures and physical contacts. For control between the Telenoid and Face conditions, hugs in the Telenoid condition were excluded from gestures and physical contacts.

We used a paired t-test between the Telenoid and Face conditions within subjects to reveal the behavioral differences using Telenoid. We also compared the frequency of such behaviors of the first and last five trials in each condition (by Student's t-test when homoscedasticity was confirmed and Welch's t-test when unconfirmed) to determine the long-term effect.

4.3.2 Results

We conducted ten trials (interactions) for each participant. The average duration of an interaction was 709.1 sec (SD = 316.2) for the Face condition and 798.7 sec (SD = 383.3) for the Telenoid condition. The Telenoid condition time was longer because residents kept talking to Telenoid even after they were informed of the experiment's end.

4.3.2.1 Ms. A: 96 years old

■4.3.2.1.1 Diagnosis of Dementia Ms. A was diagnosed as AD in 2006. The test results for the diagnosis of dementia before and after the experiment are shown in Table 4.1.

Table 4.1 Diagnosis of dementia test result of Ms. A

		before (11/13/2014)	after (3/26/2015)
MMSE		12/30	13/30
QOL-D	Positive affect	28/28	28/28
	Negative affect and actions	8/24	7/24
	Ability of communication	20/20	20/20
	Restlessness	8/20	7/20
	Attachment with others	10/16	14/16
	Spontaneity and activity	14/16	13/16
DBD		13/112: No major problem in mental and behavioral disorder	8/112: No major problem in mental and behavioral disorder
NPI-NH		Agitation/aggression Frequency 1, severity 1, caregiver distress 1	None
BI		45/100	45/100
VTI		8/10	8/10

Her MMSE score were 12 (before) and 13 (after), indicating that Ms. A had moderate dementia. However, BPSD, which was previously observed when she was staying at home and in another geriatric health service facility, did not appear in the current group home. During the experiment, an episodic memory disorder was discovered in Ms. A. No other remarkable cognitive impairments were found.

We conducted several trials, but she did not remember what she had experienced in the previous meetings with Telenoid. In the Face condition she tended to describe the pleasure of her past in a vivid manner. The content of the conversation was only about her past, and not much about the speaker. She did not remember the recent news, and showed a gloomy look on her face when she talked about it. When interacting through Telenoid she seemed to consider that the robot was a child, and then she became expressive and started talking aloud with Telenoid. When she talked to Telenoid, she asked about what it wanted to be in the future, displaying conversation fluency. She tended to physically interact with Telenoid by giving hugs and kisses, and touching head to head. Such physical behaviors were not found in the Face condition.

■4.3.2.1.2 Questionnaire The questionnaire results are shown in Table 4.2. Comparing the averages from the Telenoid and Face conditions, we found significant differences in Sp_Q4 (Telenoid > Face, $t = -2.75$, $p < 0.05$), Ob_Q3 (Telenoid < Face, $t = 3.28$, $p < 0.01$), and Ob_Q4 (Telenoid > Face, $t = -3.87$, $p < 0.01$). Comparison between the first/last halves showed differences in Face condition's Sp_Q1 ($t = -1.90$, $p < 0.10$), Sp_Q6 ($t = -2.14$, $p < 0.10$), and Ob_Q1 ($t = -2.13$, $p < 0.10$). These results showed improvement in the communication in the later five trials.

Table 4.2 Questionnaire results for trials with Ms. A. Left column indicates overall comparison results between the Telenoid condition and the Face condition; Righthand two columns indicate first/latter half period summary for each condition. Values in the table indicates: mean score, SD (in parenthesis), *t*-test result where $*$: $p < 0.1$, $**$: $p < 0.05$, $***$: $p < 0.01$.

					Telenoid			Face		
		Telenoid	Face	*p*	first half	last half	*p*	first half	last half	*p*
Speaker	Q1	3.6 (0.84)	4.1 (0.57)		3.8 (0.84)	3.4 (0.89)		3.8 (0.45)	4.4 (0.55)	*
	Q2	3.6 (0.84)	3.7 (0.95)		3.6 (0.55)	3.6 (1.14)		3.6 (0.89)	3.8 (1.10)	
	Q3	3.4 (0.70)	3.4 (0.70)		3.6 (0.55)	3.2 (0.84)		3.2 (0.84)	3.6 (0.55)	
	Q4	4.4 (0.70)	3.6 (0.70)	**	4.6 (0.55)	4.2 (0.84)		3.6 (0.55)	3.6 (0.89)	
	Q5	3.7 (0.82)	3.7 (0.67)		3.6 (0.55)	3.8 (1.10)		3.4 (0.89)	4.0 (0.00)	
	Q6	3.3 (1.25)	3.4 (0.70)		3.2 (1.10)	3.4 (1.52)		3.0 (0.71)	3.8 (0.45)	*
	Q7	2.8 (0.63)	2.7 (0.95)		2.8 (0.45)	2.8 (0.84)		2.4 (1.14)	3.0 (0.71)	
Observer	Q1	4.1 (0.74)	4.0 (0.82)		3.8 (0.84)	4.6 (0.55)		3.6 (0.55)	4.6 (0.89)	*
	Q2	4.0 (0.94)	3.9 (0.57)		3.6 (1.14)	4.0 (1.22)		3.6 (0.55)	4.2 (1.30)	
	Q3	3.1 (0.88)	3.8 (1.03)	***	2.8 (0.84)	3.6 (0.89)		3.6 (1.14)	4.0 (1.00)	
	Q4	4.5 (0.71)	3.5 (0.85)	***	4.8 (0.45)	4.4 (0.55)		3.4 (1.14)	3.6 (1.14)	
	Q5	4.0 (0.94)	3.6 (0.70)		4.2 (1.10)	3.4 (0.55)		3.2 (0.45)	3.4 (1.14)	
	Q6	3.5 (1.08)	2.9 (0.57)		3.8 (0.84)	3.4 (1.14)		2.8 (0.45)	3.0 (0.71)	
	Q7	3.3 (0.82)	3.5 (0.53)		3.4 (0.55)	3.2 (0.84)		3.2 (0.45)	3.4 (0.55)	

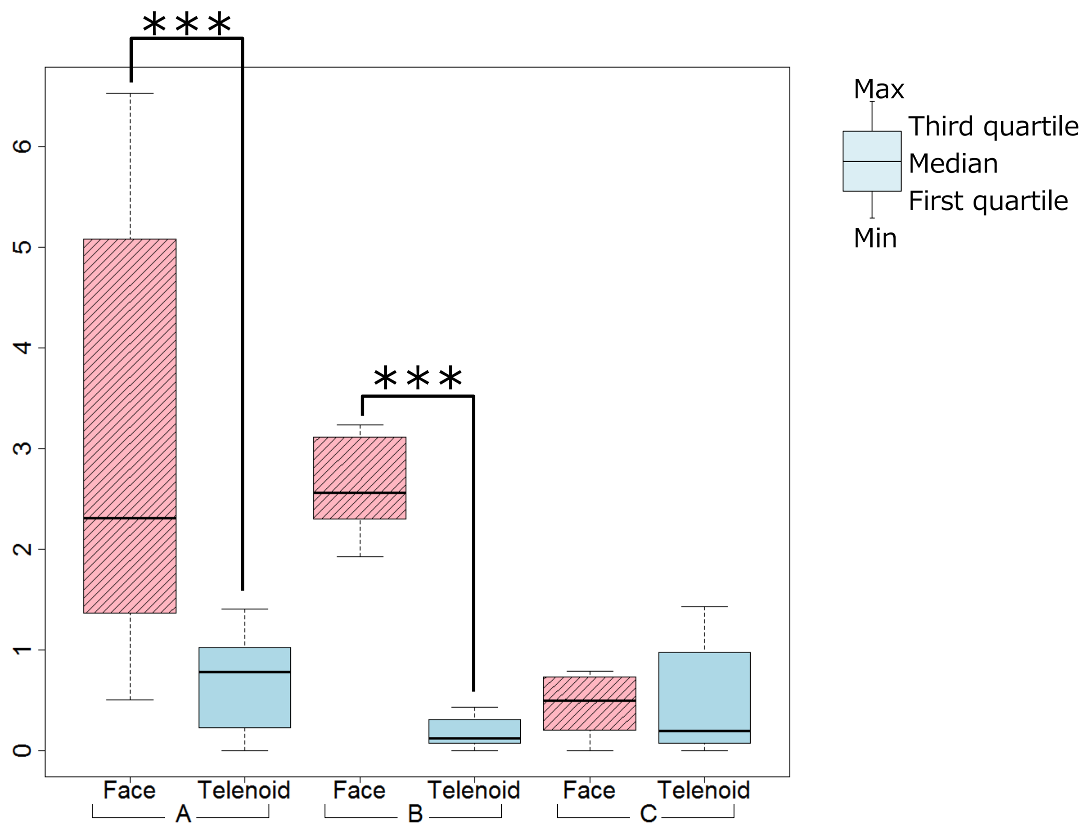


Fig. 4.3 Gesture Tendency ($*$: $p < 0.1$, $**$: $p < 0.05$, $* * *$: $p < 0.01$)

■4.3.2.1.3 Video Analysis We used a paired t-test between the Telenoid and Face conditions and found significant differences for the frequency of gesture (Telenoid < Face, $t = 3.75$, $p < 0.01$), and the frequency of physical contact (Telenoid > Face, $t = -5.40$, $p < 0.01$) (Figure 4.3, 4.4). We did not find significant differences for the frequency of gestures or physical contact between the first and last five trials.

4.3.2.2 Ms. B: 93 years old

■4.3.2.2.1 Diagnosis of Dementia Ms. B was diagnosed as AD in 2010. The test results for the diagnosis of dementia before and after the experiment are shown in Table 4.3.

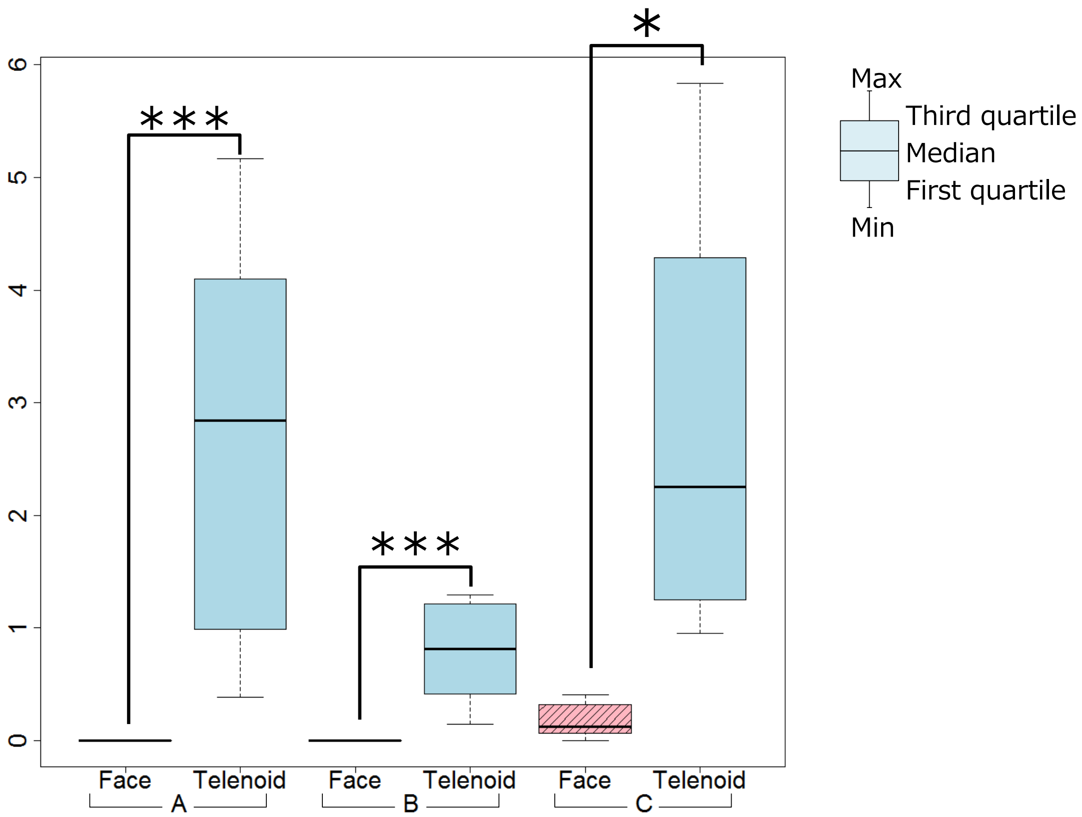


Fig. 4.4 Physical Contact Tendency ($*$: $p < 0.1$, $**$: $p < 0.05$, $***$: $p < 0.01$)

Table 4.3 Diagnosis of dementia test result of Ms. B

		before (9/4/2014)	after (3/26/2015)
MMSE		17/30	14/30
QOL-D	Positive affect	28/28	20/28
	Negative affect and actions	12/24	10/24
	Ability of communication	20/20	20/20
	Restlessness	11/20	8/20
	Attachment with others	16/16	16/16
	Spontaneity and activity	16/16	16/16
DBD		25/112: Defect of memory and fecal incontinence	26/112: Defect of memory and fecal incontinence
NPI-NH		None	Agitation/aggression Frequency 4, severity 1, caregiver distress 1 Anxiety Frequency 4, severity 1, caregiver distress 2
BI		85/100	85/100
VTI		8/10	9/10

Ms. B had a gentle personality, but sometimes she rejected care and had problems with other residents and caregivers. She had severe episodic memory disorder and rarely remembered what she experienced in previous meetings with Telenoid and speakers. Her MMSE scores were 17 (before) and 14 (after), which indicates that she had moderate dementia. Mental and physical problems were rarely found by the tests, and she was generally calm during the experiments. She talked about herself in the Face condition, while asking more questions and making physical contact in the Telenoid condition.

■4.3.2.2.2 Questionnaire The questionnaire results are shown in Table 4.4. Comparing the averages from the Telenoid and Face conditions, we found significant trends in Sp_Q4 (Telenoid > Face, $t = -1.92$, $p < 0.10$), Sp_Q6 (Telenoid > Face, $t = -1.86$, $p < 0.10$), Ob_Q1 (Telenoid > Face, $t = -2.06$, $p < 0.10$), Ob_Q4 (Telenoid > Face, $t = -2.21$, $p < 0.10$), and Ob_Q5 (Telenoid > Face, $t = -2.23$, $p < 0.10$). We also found significant differences in Ob_Q6 (Telenoid > Face, $t = -2.69$, $p < 0.05$). Comparison between the first/last halves showed significant trends in Telenoid condition's Ob_Q3 ($t = -2.14$, $p < 0.10$) and significant differences in Face condition's Sp_Q7 ($t = -2.36$, $p < 0.05$). These results showed improvement in communication in the last five trials.

Table 4.4 Questionnaire results for trials with Ms. B. Left column indicates overall comparison results between the Telenoid condition and the Face condition; Righthand two columns indicate first/latter half period summary for each condition. Values in the table indicates: mean score, SD (in parenthesis), t-test result where $*$: $p < 0.1$, $**$: $p < 0.05$, $***$: $p < 0.01$.

					Telenoid			Face		
		Telenoid	Face	p	first half	last half	p	first half	last half	p
Speaker	Q1	3.4 (1.07)	3.7 (0.82)		3.4 (1.14)	3.4 (1.14)		3.4 (0.89)	4.0 (0.71)	
	Q2	3.5 (1.08)	3.5 (0.85)		3.6 (0.89)	3.4 (1.34)		3.2 (0.84)	3.8 (0.84)	
	Q3	3.3 (0.67)	3.1 (0.74)		3.0 (0.71)	3.6 (0.55)		3.2 (0.84)	3.0 (0.71)	
	Q4	4.1 (0.88)	3.3 (0.67)	*	4.0 (0.71)	4.2 (1.10)		3.2 (0.45)	3.4 (0.89)	
	Q5	2.9 (0.88)	3.1 (0.99)		3.0 (0.71)	2.8 (1.10)		3.0 (1.00)	3.2 (1.10)	
	Q6	3.6 (0.84)	3.1 (0.88)	*	3.4 (0.89)	3.8 (0.84)		3.2 (0.84)	3.0 (1.00)	
	Q7	3.0 (0.82)	3.3 (0.82)		3.0 (1.00)	3.0 (0.71)		2.8 (0.84)	3.8 (0.45)	**
Observer	Q1	4.0 (0.94)	3.2 (1.03)	*	4.2 (1.10)	3.8 (0.84)		3.2 (0.84)	3.2 (1.30)	
	Q2	3.7 (0.95)	3.4 (0.97)		3.8 (1.30)	3.6 (0.55)		3.2 (0.84)	3.6 (1.14)	
	Q3	3.4 (0.70)	3.3 (0.67)		3.0 (0.71)	3.8 (0.45)	*	3.0 (0.00)	3.6 (0.89)	
	Q4	4.1 (0.74)	3.2 (1.03)	*	3.8 (0.84)	4.4 (0.55)		2.8 (0.84)	3.6 (1.14)	
	Q5	3.7 (0.82)	2.9 (0.74)	*	4.0 (0.71)	3.4 (0.89)		2.6 (0.55)	3.2 (0.84)	
	Q6	3.5 (0.71)	2.8 (0.63)	**	3.6 (0.89)	3.4 (0.55)		2.6 (0.55)	3.0 (0.71)	
	Q7	3.1 (0.74)	3.3 (0.48)		2.8 (0.84)	3.4 (0.55)		3.2 (0.45)	3.4 (0.55)	

■4.3.2.2.3 Video Analysis We used a paired t-test between the Telenoid and Face conditions and found significant differences for the frequency of gestures (Telenoid < Face, $t = 11.09$, $p < 0.01$), and the frequency of physical contact (Telenoid > Face, $t = -4.89$, $p < 0.01$) (Figure 4.3, 4.4). We did not find any significant differences for the frequency of gestures or physical contact between the first and last five trials.

4.3.2.3 Ms. C: 85 years old

■4.3.2.3.1 Diagnosis of Dementia Ms. C was diagnosed as AD in 2004. Her test results for the diagnosis of dementia before starting the experiments are shown in Table 4.5. Ms. C was transferred to a special nursing home for the elderly at the end of the experiment and could conduct the test after the experiment. Group home for the elderly with dementia is usually for the seniors with mild dementia, who need a little support to live by them. Ms. C was in the home because there was no spare room in the special nursing home at the beginning of the experiment. She moved to the special nursing home when there was a spare room.

Table 4.5 Diagnosis of dementia test result of Ms. C before (9/4/2014)

MMSE		0/30
QOL-D	Positive affect	23/28
	Negative affect and actions	15/24
	Ability of communication	6/20
	Restlessness	5/20
	Attachment with others	12/16
	Spontaneity and activity	6/16
DBD		22/112: Apathy, refusal, and incontinence were found
NPI-NH	Hallucinations	Frequency 4, severity 1, caregiver distress 0
	Agitation/aggression	Frequency 4, severity 1, caregiver distress 1
	Anxiety	Frequency 4, severity 1, caregiver distress 1
	Apathy	Frequency 4, severity 1, caregiver distress 0
	Disinhibition	Frequency 4, severity 1, caregiver distress 1
	Irritability	Frequency 4, severity 3, caregiver distress 1
	Aberrant motor behavior	Frequency 4, severity 1, caregiver distress 1
BI		45/100
VTI		8/10

Her MMSE score was 0, indicating severe dementia. She tended to make ambiguous statements and repeat the same phrases. Verbal communication was difficult with her; however, she did not often show a problematic BPSD, and the caregiver distress points were not high. She held eye contact in the Face condition; however, the content of her conversation was difficult to understand. Similar behavior was observed in the Telenoid condition. But she played peekaboo with Telenoid, suggesting that she thought she was interacting with a baby.

■4.3.2.3.2 Questionnaire Since Ms. C was transferred to a special nursing home for the elderly at the end of the experiment, we could not measure the diagnosis of dementia after the experiment for Ms. C. However, the questionnaire result and video analysis result during the experiment is measured in a same way as Ms. A and Ms. B.

The questionnaire results are shown in Table 4.6. Comparing the averages from the Telenoid and Face conditions, we found significant differences in Sp_Q2 (Telenoid < Face, $t = 2.45$, $p < 0.05$). Comparison between the first/last halves showed significant differences in Face condition's Ob_Q1 ($t = -2.75$, $p < 0.05$), Ob_Q2 ($t = -5.77$, $p < 0.01$), and Ob_Q3 ($t = -2.89$, $p < 0.05$). These results showed improvement in the communication in the last five trials.

Table 4.6 Questionnaire results for trials with Ms. C. Left column indicates overall comparison results between the Telenoid condition and the Face condition; Righthand two columns indicate first/latter half period summary for each condition. Values in the table indicates: mean score, SD (in parenthesis), t-test result where $*$: $p < 0.1$, $**$: $p < 0.05$, $***$: $p < 0.01$.

					Telenoid			Face		
		Telenoid	Face	p	first half	last half	p	first half	last half	p
Speaker	Q1	2.2 (1.03)	2.8 (0.92)		2.4 (1.14)	2.0 (1.00)		2.8 (1.10)	2.8 (0.84)	
	Q2	2.2 (1.14)	3.0 (1.05)	**	2.4 (1.52)	2.0 (0.71)		2.8 (1.30)	3.2 (0.84)	
	Q3	2.0 (0.94)	2.2 (0.92)		2.2 (1.30)	1.8 (0.45)		2.4 (1.14)	2.0 (0.71)	
	Q4	3.8 (1.23)	3.6 (0.52)		3.4 (1.34)	4.2 (1.10)		3.6 (0.55)	3.6 (0.55)	
	Q5	3.1 (0.88)	3.0 (0.94)		3.2 (0.84)	3.0 (1.00)		2.6 (0.89)	3.4 (0.89)	
	Q6	2.7 (0.95)	2.2 (0.63)		2.6 (1.14)	2.8 (0.84)		2.0 (0.71)	2.4 (0.55)	
	Q7	2.3 (0.95)	2.1 (0.99)		2.2 (1.30)	2.4 (0.55)		1.8 (0.84)	2.4 (1.14)	
Observer	Q1	2.3 (0.95)	2.7 (1.06)		2.2 (0.84)	2.4 (1.14)		2.0 (1.00)	3.4 (0.55)	**
	Q2	2.1 (0.88)	2.6 (1.17)		2.0 (1.00)	2.2 (0.84)		1.6 (0.55)	3.6 (0.55)	***
	Q3	2.3 (1.06)	2.1 (0.74)		2.0 (1.00)	2.6 (1.14)		1.6 (0.55)	2.6 (0.55)	**
	Q4	3.5 (0.85)	3.3 (0.95)		3.8 (0.84)	3.2 (0.84)		3.4 (1.14)	3.2 (0.84)	
	Q5	2.9 (0.99)	2.7 (0.67)		3.0 (1.00)	2.8 (1.10)		2.6 (0.55)	2.8 (0.84)	
	Q6	2.7 (0.82)	2.3 (0.67)		2.8 (0.84)	2.6 (0.89)		2.4 (0.55)	2.2 (0.84)	
	Q7	2.4 (0.70)	2.6 (0.70)		2.6 (0.55)	2.2 (0.84)		2.6 (0.89)	2.6 (0.55)	

■4.3.2.3.3 Video Analysis We used a paired t-test between the Telenoid and Face conditions and did not find significant differences for the frequency of gestures. However, we did find a significant trend in the frequency of physical contact (Telenoid > Face, $t = -2.06$, $p < 0.10$) (Figure 4.3, 4.4). We also did not find significant differences in the frequency of gestures or physical contact between the first and last five trials.

4.3.3 Discussion

4.3.3.1 Ms. A

When we compared the scores between the Telenoid and Face conditions, both Q4s from the speakers and observers were significantly positive for the Telenoid condition (Table 4.2). This means that Ms. A showed a more positive reaction when talking to Telenoid than talking face-to-face. In the Telenoid condition, she changed her voice tone as if talking to a child. She seemed to treat Telenoid like a child, which allowed her to communicate in a more relaxed manner, leading to a positive Q4 score for the Telenoid condition. In fact, there were comments on the questionnaire. Immediately after she met Telenoid, she said, "you are so cute. I love you." Whereas in the face-to-face condition, even though she seemed nervous at the beginning of the interaction, she gradually managed to have a smooth conversation. We compared the questionnaire scores for the first and last five trials. In the Face condition, Sp_Q1, Sp_Q6, and Ob_Q1 had significant differences; they increased in the latter trials. The participant talked cheerfully with Telenoid from the beginning and did not have any significant differences between the first and latter five trials.

For Ob_Q3 (Quality of conversation), the Telenoid condition's score was negative compared with that in the Face condition. This might be because the participant recognized Telenoid as a child and the conversation' s content was playful. From the video analysis results, the participant tended to make physical contact in the Telenoid condition and used gestures in the Face condition. This indicates that she used physical interactions with Telenoid instead of verbal communication, as if taking care of a child. In fact, she tended to physically interact with Telenoid by hugs and kisses and touching its head. Such physical behaviors were not found in the Face condition.

4.3.3.2 Ms. B

When we compared the Telenoid and Face conditions, both Q4s and Q6s from the speakers and observers were significantly or marginally positive for the Telenoid condition (Table 4.4).

The speakers also often adapted to the participants by changing their voice using a voice changer to sound more like a child.

The video analysis showed that in the Telenoid condition the participant made more physical contact, which was rarely observed in the Face condition. This was expected since physical interactions are usually only held among close relations. The speaker observed such interactions through the monitor, which might cause her to have better conversations with more emotional expressions. During the conversation, Ms. B seemed to interact with Telenoid as if it were a child, as in the case of Ms. A. Ms. B became calm when talking with Telenoid, which might explain the positive result in Q4 in the Telenoid condition. In fact, several questionnaire comments said that the participant seemed to become nervous at the beginning of the interaction in the Face condition with less eye contact, while conversely other comments said that the participant was relaxed and smiled more often to Telenoid.

We found that the emotional state of the speaker (Q6) became positive because the speaker experienced a more positive reaction from Ms. B through Telenoid. Telenoid affected the participant positively, resulting in a different quality of interaction, which the speaker enjoyed. Thus, Telenoid improved the conversation of both the participant and the speaker. There were also positive face-to-face conversations between Ms. B and the speaker; however, in the Telenoid condition the speaker observed the interactions from a third-person point of view, which allowed the speaker to participate in conversations objectively and have more positive feedback than in the Face condition.

4.3.3.3 Ms. C

When comparing the questionnaire scores for the first and last five trials, Face condition's Ob_Q1, Ob_Q2, and Ob_Q3 had significantly positive points for the latter half (Table 4.6). This suggests that the speaker adapted to the participant in the latter half, although it was difficult at the beginning.

Compared with the Face condition, Sp_Q2 (Amount of conversation) was significantly negative in the Telenoid condition. For the participant who had difficulty in the conversations, nonverbal information becomes more important. In the Telenoid condition, the speaker operating Telenoid only received limited information through the camera. The limited information may cause difficulty for the speaker during conversation, lowering scores. One of the speaker's comments on the questionnaire said, "Nonverbal information, like holding hands and eye contact, is important, but communicating this through Telenoid was difficult." There were no such comments by the observers.

In the video analysis, we found no significant differences between the Telenoid and Face conditions for the frequency of gesture tendency, while the frequency of physical contact was significantly higher for the Telenoid condition. This indicates that the participant was also attempting to have nonverbal communication with Telenoid, the same as in the Face condition. Therefore, the speaker's questionnaire scores might rise by improving the Telenoid operating system to support more nonverbal communication. The results also indicate that Telenoid might be a viable platform for communicating with seniors with severe dementia.

4.3.3.4 Overall Discussion

All three participants tended to have more physical contact in the Telenoid condition. This result also implies that participants interacting with Telenoid were less nervous from the beginning of the conversation. They treated Telenoid as a child, which is huggable and easier to touch. Since it is huggable, they felt free to interact with it from the beginning.

The results suggest that because Telenoid has a physical presence, the elderly can hold it and they also like its child-like appearance. We believe such results cannot be seen by existing robots, including telepresence robots or Paro. To support communication by robots, especially for seniors with dementia, the robot' s appearance has to be in a form that the elderly can recognize and talk to at a relatively close distance that simplifies physical interaction. The close distance allows elderly to recognize a robot easily and enable to touch, which is important to establish a good relationship [8].

The Q4 scores (participant's impression) from both Ms. A and Ms. B supported the Telenoid condition. Ms. A and Ms. B tended to make more gestures in the Face condition. The reason might be because the participants had difficulty moving their upper body to make gestures while holding Telenoid.

Compared with Ms. A and Ms. B, since Ms. C has severe AD, verbal communication is more difficult with her. Ms. C tended to use more gestures in conversation and showed no significant differences in gesture tendency between the Telenoid and Face conditions.

4.3.4 Summary

We discussed the possibility of introducing a teleoperated robot into an elderly care house for long-term interaction. We compared two conversation conditions: face-to-face and using a teleoperated robot, Telenoid. Our experiment results showed that two participants with moderate AD had positive reactions from talking with Telenoid. The result supports the previous research about positive reaction of elderly using Telenoid [112], and moreover, we found the result compared to face-to-face communication for long term.

The third participant had severe AD, and it was difficult to verbally communicate with her. However, she interacted with Telenoid using nonverbal communication in a way that resembled the face-to-face condition. Thus, we conclude that Telenoid may trigger positive emotions in residents with moderate AD and suggest the possibilities of nonverbal communication with residents with severe AD as well.

To introduce a robot to elderly care houses, caregivers must constantly use it and residents must be discouraged from losing interest in it. We compared the questionnaire results of the first and latter five trials and found significant differences or tendencies for five items in the Face condition and 1 item in the Telenoid condition, indicating that in the Face condition, people had better conversations as the experiment went on, and in the Telenoid condition, the quality of the conversation remained high. As for the face-to-face conversation, we believe this is because both the seniors and the speakers felt nervous at the beginning and took time to have effective conversations. On the other hand, people communicated smoothly through Telenoid from the beginning. The Telenoid condition had fewer items to improve in the latter five trials; however, no item worsened. This indicates that Telenoid did not lose the interest of the residents, not even at the end of the experiment. The robot we used in this study, Telenoid, is teleoperated and the operator can behave and speak in a variety of ways. Such nature of Telenoid may make it more alive, and interacting with Telenoid will likely to appear to be closer to human-human interaction than other robots such as Paro, QRIO or Robovie as mentioned in the previous section. Since the state-of-art of artificial intelligence technology is quite limited, especially for having conversation with people, the teleoperation system used in Telenoid seems to be a very effective and practical solution.

The Telenoid users monitored the positive reactions of participants through a camera. The speaker may become motivated to better care for the patients by watching such interactions that cannot be seen in face-to-face communication. If caregivers were to use Telenoid, they might become emotionally expressive and enjoy conversations with seniors, boosting their motivation to care for those living with dementia. Observing the residents from a third-person point of view and communicating in a manner that is not possible face-to-face might improve caregiver attitudes, resulting in better relationships and an improved atmosphere in the facility. This could help caregivers and facility residents get to know each other better and eventually lower the turnover rate for the former.

If seniors suffer from severe AD, they rarely respond to care. As a result, caregivers have difficulty communicating with their charges and become discouraged. Observer's questionnaire result shows that the impression of residents with mild AD will become more cheerful when talking to Telenoid. This indicates that caregivers observing the interaction between Telenoid and the residents can notice the cheerful behavior of the residents, which might motivates caregivers. Also, if the caregiver met the resident for first time, the caregiver might have difficulty talking to the resident. By using Telenoid, the caregiver can easily have a conversation and understand the characteristics of the resident, which can be useful for the next meeting.

Caregivers sometimes have difficulty telling residents to do something. Residents sometimes refuse to wake up in the morning or eat lunch. Such refusal, which is caused by BPSD, can sometimes be solved by interacting with others. In such cases, Telenoid might be used as other people and interact with residents.

However, the experiment did not prove the effect of Telenoid itself, since the speakers had conversations both with Telenoid and face-to-face. Having conversations through Telenoid might reduce the nervousness of a speaker who is talking face-to-face, or the opposite effect might have happened. Although the speakers and residents experienced conversations in both forms, the Telenoid results showed significantly higher evaluations. Therefore, the Telenoid conversations outperformed the face-to-face conversations, but no cross effect are clear from the results here. We have to add a speaker-only condition using the Telenoid condition and only the face-to-face condition to reveal such an effect.

Another limitation of the current study lies in that its results do not show the effect of using Telenoid in comparison with other robots. We found positive results in the Telenoid conditions, perhaps not because of Telenoid, but since seniors with AD forgot the previous meetings. Future work has to include other robots and compare them to reveal long-term effects. So far we have only acquired a partial result with Telenoid because experimenters and volunteers were necessary for supporting the experiment. Caregivers had difficulty setting up Telenoid and using it properly since they were too busy with other tasks If the volunteers at the facility can operate Telenoid from their homes, the load of using it will decrease. We will consider a plan that introduces Telenoid and its appropriate usage in future work.

4.4 How Imagination Works

In this section, we discuss how seniors with dementia recognize others and communicate from a case study of observing one senior interacting with teleoperated robot “Telenoid”.

Telenoid is a telecommunication medium which transfers operator’s head motion and voice. For example, senior’s families or volunteer staffs can operate it and they can communicate with the seniors living in the care facility or single-living seniors through it. It promises to create more opportunities for the seniors to socialize with others. Our previous work in Japan and Denmark revealed that Telenoid motivated seniors with dementia to communicate with others, and those people tended to communicate more often by using it [44, 112, 115]. Why did seniors with dementia show such responses to Telenoid? We have hypothesized that seniors might have a function to complement lack of information and Telenoid might trigger them to imagine and complement the impression of it positively.

Telenoid is a teleoperated robot with a unique appearance (Figure 4.5). It is small (about 80 cm), lightweight (about 3 kg) and covered with soft skin (vinyl chloride) for users to easily hold and talk. It has a limited range of motion (head, mouth, and arm), and the arm can only perform the act of hugging. The mouth can open and close synchronized with the utterances of the operator. These motions are limited for telecommunication, and it cannot transfer nor show expression. Telenoid has a simplified appearance and functions. People might have felt weird about the simplified and the plain appearance of it, however, they got used to it after few minutes of interactions [69]. Seniors, especially seniors with dementia, did not show any discomfort from the beginning, and often hugged and talked without any instruction.

As explained above, Telenoid is a remotely controlled interactive medium. It needs an operator and cannot talk by itself. It is like a moving phone which transfers remote person's voice and head movement, but different from the phone since the user of Telenoid can hold and feel it moving. However, the user cannot see the face of the operator nor details such as expression and gesture like a video chat. Users need to imagine whom they are talking to. Seniors with dementia who interact with Telenoid sometimes say that Telenoid is smiling, although Telenoid cannot show facial expression. We believe that the seniors can imagine the facial expression from the contents of dialogue and the behavior of Telenoid. Seniors with dementia sometimes do not listen to the Telenoid (operator), or fail to listen but continue the conversations. We think that seniors with dementia also imagine and complement the contents to communicate.

It is well known that such complementation of information occurs generally to us. Although an eyeball has a blind spot due to the structure, we do not feel like there is a hole in our sight. Also, we can communicate with others in noisy environments. These are because complementation is working unconsciously. Such complementation occurs frequently for aged people which have low physical and cognitive function. Previous studies have shown that elderly people and hearing-impaired people are more dependent on context clues than young people. For example, Pichora-Fuller *et al.* conducted listening test answering to the last word among young people, elderly people, and old-age hard-of-hearing people, and it revealed that elderly people and old-age hard-of-hearing people relied more on contexts when listening [33]. McCoy *et al.* conducted a similar listening test on elderly people and light/moderate hearing impairment elderly people, and it revealed that the percentage of correct answers declined significantly for hearing impaired elderly people with words unpredictable from the context [50]. There were dialogues, which elderly people with dementia seemed to take in turn but they were not talking about same topic. Such dialogue happened because both seniors complemented the lack of information incorrectly. They might have failed to listen, and they predicted and complemented from other information, such as facial emotions and timing of utterances. Since both misunderstood, they kept the conversations.

Imagination and complementation may result negative. People worry about something and have a bad image when the situation is unclear. One symptom of dementia called "delusion of theft" [27, 61] might be also an example of imagining negatively. It seems like "hug" and "simplified information" are factors of Telenoid which enhances positive imagination and complementation for seniors with dementia. The user holds Telenoid to communicate. Hall described the interpersonal distances of man into four zones, and the closest zone is reserved for people in good relationship, such as good friends, lovers, or family [22]. It is known that the behavior of hug enhances users to have a positive impression for the conversation partner [46]. People who hug needs to be in the closest distance, and the behavior of hug may lead to bias to have an imagination positively. Since Telenoid is small, the user might think it as an infant and babysitting. The function of it is simplified and it cannot express details such as the facial expression of the operator. It cannot express positive feelings such as smiling nor negative feelings such as frustration. Telenoid cannot move by itself, so it will stay in arms and will not get bored and go away like a child. It does not have an ability to express detail feelings of the operator, which may look like a calm child whom listen to the users and lead to have a positive impression.

We speculate that Telenoid is favored by seniors with dementia and there are following reasons of motivating dialogue:

1. Strong information complements actions from decreased ability of cognitive and sensory functions of seniors with dementia
2. Function of Telenoid simplifies information to imagine
3. Hugging behavior enhances the positive bias

Then, is it possible to motivate seniors with dementia to communicate more by simplifying information of Telenoid? If seniors with dementia speak more to a functionally limited robot, the result may support further understanding of the cognitive mechanism of the seniors. We might understand the internal mental states like anxious feelings or physical problems from the context of the dialogue, which can be used for nursing care. There is also a report that dialogue relieved the symptoms of dementia [14], so it may be possible to suppress the progress of dementia and BPSD.

In this context, we observed the responses of seniors with dementia using a mock-up of Telenoid. Here, the mock-up is a mannequin of Telenoid which has the same covered skin, weight, and center of gravity, but the inside is just clay and cushion (Figure 4.5(a)). The following is case studies of one senior with dementia, who had experienced talking to Telenoid, interacting with Telenoid. We discuss how seniors with dementia recognize others and communicate with others by comparing the case studies of one senior interacting with teleoperated Telenoid or the mock-up.

4.4.1 Design and Methods

The participant is one female senior with dementia (100s age), who had experienced talking to teleoperated Telenoid and had shown a positive reaction to it. She lives in a special nursing home for elderly and usually sits at the table in the public space to sleep. When she is awake, she often interacts with other residents and caregivers offensively. The mock-up was placed for 1 month from December 2013 so caregivers could hand it to the participant anytime. The interactions were recorded by a camera.

We also recorded interactions of the participant and teleoperated Telenoid before and after the mock-up trials. The experimenter operated Telenoid in a teleoperated condition. We compared conditions of teleoperated and the mock-up to evaluate the relation between the amounts of information and complementation. Interactions in each condition ended when the participant lost her interest or before meals or cares.

This experiment was approved by ethics committee of the Advanced Telecommunications Research Institute International (No. 13-507-1). Informed consent was obtained from the manager of the facility, her doctor, and her families.

4.4.2 Results

Five interactions in total with the mock-up were recorded (Figure 4.6). Three interactions were used to analyze, since the other two were not recorded from the beginning or until the end of the interactions. The recorded interactions of the participant and teleoperated Telenoid before (November 2013) and after (February 2014) the mock-up trials (Teleoperated Conditions 1 and 2) were used for the comparison.

The experimenter analyzed the recorded movie and counted how many the participant talked to Telenoid. The utterances that could not be identified whom she was talking to and which persons she was talking to, such as caregivers or other residents, were ignored. Since the utterances of the participant were unclear and often difficult to understand, an utterance without a breath was counted as one utterance in such cases.

The average time of the interactions was 22 minutes for the Mock-up Condition and 28 minutes for the Teleoperated Condition (Figure 4.7(a)). The average number of her utterances was 2.5 times/min for the Mock-up Condition and 6.1 times/min for the Teleoperated Condition (Figure 4.7(b)).

4.4.2.1 Mock-up Condition 1

The interactions are shown in Table 4.7. At first, the participant sat on a seat and was reading a book. The mock-up was placed on the table in front of the participant, but she was reading the book and seemed like she did not notice to the mock-up. A caregiver picked up the mock-up, handed it to the participant, and the interactions began. When the participant noticed the mock-up, she received it with both hands. She talked to the mock-up with the name she named. She then placed the mock-up on the table and adjusted the blanket covered over the mock-up several times. After 7 minutes, she asked caregivers to get a baby holder, but caregivers could not find it and she got mad. After 14 minutes, she started to sleep with holding the mock-up. She did seem to not notice that it was a mock-up and treated it like a baby.

4.4.2.2 Mock-up Condition 2

The interactions are shown in Table 4.8. A caregiver gave the mock-up to the participant when she was sitting on the seat and doing nothing. The participant smiled when she noticed the mock-up and said, “Did you come alone?” or “Isn’t it cold?” She also asked the mock-up whether it got money from its mother to come here. After 10 minutes of the interactions,

Table 4.7 Interactions in mock-up condition 1

Time	Interaction
0:00	The participant is reading a book, and the mock-up is on the table.
0:31	Caregiver picks up the mock-up and gives it to the participant.
	The participant holds up, saying it is heavy and placed on the table.
1:32	Repeatedly holds mock-up, talks to it several times, and places on the table.
7:43	Asks caregivers to get a baby holder.
8:30	Gets mad at the caregiver who was nursing the resident sitting next to the participant.
10:07	Gets interested to the book and pick up it but suddenly puts it back on the table.
10:50	Talks to the person next to the participant.
14:30	Falls into a doze and starts to sleep.

she started getting irritated about money, got offensive, and shouted to other residents and caregivers. After 16 minutes, the caregiver tried to get the mock-up but the participant said, "Leave it here," and denied to take. After 19 minutes, the participant asked the mock-up, "Call me grandma." Although there was no respond from the mock-up, she said, "You won't say because you don't know who I am" and kept talking to it. She often placed it on the table and seemed like she got it off to sleep. She suddenly placed it on the table and interacted with other residents. After 36 minutes, the caregiver told the participant that the mock-up was going to get meal, and then it was taken away from her.

4.4.2.3 Mock-up Condition 3

The interactions are shown in Table 4.9. The participant was lying on the table and sleeping. A caregiver held a mock-up, sat next to the participant, and woke up the participant. The participant said, "(Pick a) boo!" soon after she woke up and noticed the mock-up. About 90 seconds later, she said, "Heavy," "There there," etc., and then put the mock-up on the table. Then, she picked up the mock-up upside down. When the participant held the mock-up upside down, the caregivers mentioned that it was upside down twice. However, she did not listen to the caregivers and kept it upside down. After 6 minutes of interactions, she placed it on the table and held again. At that time, she held it with its head up. The participant began to feel drowsy after 8 minutes. She placed it on the table after 16 minutes of interactions and adjusted the blanket but failed to cover it. Then she started to sleep with the mock-up in her hand.

Table 4.8 Interactions in mock-up condition 2

Time	Interaction
0:00	Interactions begin from the participant sitting and the caregiver brings the mock-up.
0:50	The participant says, "You came by yourself? Great!" to the mock-up held by the caregiver and she receives it.
1:06	Gets mock-up off to sleep and becomes quiet.
1:27	Talks to the mock-up and holds up. Then hugs and talks into the face.
2:27	Lays the mock-up on the table and talks to it.
2:57	Talks to the mock-up and picks it up. Laughs while talking.
4:54	Lays the mock-up and becomes quiet.
6:04	Covers the mock-up with the blanket given by the caregiver.
	Repeats holding and laying on the table several times.
	Talks to mock-up saying, "Isn't it cold?"
10:28	Talks to other resident several times.
16:34	When the caregiver tried to pick the mock-up up, the participant said, "Leave it here," and denied to pick up.
19:13	Says, "Call me grandma," and "You won't say, you don't know who I am."
22:39	Turns mock-up so it can look around.
25:33	Pushes the mock-up which is laying on the table and becomes quiet.
	Talk to another resident.
28:46	Notices the mock-up and repeats covering the blanket to it but says nothing.
33:31	Covers the mock-up with the blanket and says "It's warm".
36:43	The caregiver says the mock-up will have a meal and get it.

4.4.2.4 Teleoperated Condition 1 (before mock-up experiment)

The interactions are shown in Table 4.10. A nursing staff handed Telenoid which was teleoperated by the remote experimenter to the participant and the interactions began. The participant talked to Telenoid frequently. She said it was heavy and placed on the table several times, but held and talked to it for most of the time. Since the participant's utterances were unclear, the operator often got confused to answer. However, the participant seemed to be playing with words and enjoying the conversations. After 40 minutes, the participant tried to send Telenoid to bed and said, "Go to sleep." The experimenter picked up Telenoid and the interactions ended.

Table 4.9 Interactions in mock-up condition 3

Time	Interaction
0:00	The participant is lying on the table and sleeping.
0:35	The caregiver gets the participant up.
	The participant woke up and said at loud when she noticed the mock-up.
	She smiled and received it. She talked to the mock-up and hugged.
	Then, she did not talk at all.
1:21	Lays mock-up on the table.
2:20	Holds upside down and hugs.
3:30	The caregiver says to the participant that the mock-up is upside down, but she did refuse.
4:20	The other caregiver says that the mock-up is upside down, but she said, “Stop” and does not listen.
5:48	Placed on the table and hold again. This time, she holds with head up.
7:07	The participant asks the caregiver to get a blanket for the mock-up.
7:37	Receives the blanket and covers the mock-up.
8:00	Falls into a doze while holding the mock-up.
14:33	Lays mock-up and falls asleep.
15:49	Picks up and hold, then sleeps.
16:56	Places on the table and ends the interactions.

Table 4.10 Interactions in teleoperated condition 1

Time	Interaction
0:00	The caregiver hands Telenoid to the participant.
0:01	The participant receives it, puts on the lap, and talks to it.
0:15	Repeats laying it on the table and picking it up.
1:27	Says “Where is your sister?” and asks about the family.
2:53	Puts her head to Telenoid’s head.
3:46	Puts her head to Telenoid’s head again.
7:29	Pats Telenoid’s stomach.
12:16	Taps Telenoid’s side with both hands.
22:34	Lays Telenoid on the table and leaves it for 4 minutes without saying anything.
	Then starts to talk again.
38:48	Says, “Go to sleep,” and tries to sleep down.
40:07	The experimenter picks up Telenoid and ends the interactions.

Table 4.11 Interactions in teleoperated condition 2

Time	Interaction
0:00	The participant is holding towels on the table.
0:20	The caregiver holds Telenoid and talk to the participant.
	The participant noticed to Telenoid and said "(Pick a) boo."
	The caregiver joined the conversation with the participant and Telenoid for 3 minutes.
0:48	She asked Telenoid a name, and Telenoid said "I am Hiroshi", then she said "That is wrong."
1:07	Received Telenoid from the caregiver.
6:40	Thinks Telenoid is cold and holds tight to warm it.
7:07	Lays on the table and tries to cover it with a towel.
8:24	The caregiver joins the conversation for a minute.
9:56	Covers the blanket provided by the caregiver to Telenoid.
10:45	The meal was ready for the participant but she did not start to eat and arranged the blanket of Telenoid.
13:19	Holds Telenoid and closes her eyes. She pats the back and it seems like trying to sleep it.
15:30	The caregiver joined the conversation. The participant seems to recognize that the caregiver is Telenoid's father.
16:20	The caregiver receives Telenoid and the participant starts to eat the meal.

4.4.2.5 Teleoperated Condition 2 (after mock-up experiment)

The interactions are shown in Table 4.11. When the participant was sitting on a chair, a caregiver carried Telenoid to her. The interactions began when the caregiver passed Telenoid to the participant. The caregiver often intervened, and the participant talked to both Telenoid and the caregiver. When the participant saw Telenoid moving its arms, she said, "One, two, one, two," in accordance with the movement. When the participant asked Telenoid's name, Telenoid (operator) said, "I am Hiroshi," and the participant said, "That is wrong." She often said it was heavy and held up. After 16 minutes of interactions, the participant's meal was ready, and the caregiver received Telenoid and placed it to the next chair.

4.4.3 Discussion

In every mock-up condition, the participant did not seem like she noticed that it was a mock-up. Looking at the interaction time (Figure 4.7(a)), the participant interacted with the mock-up with no reaction. In the Mock-up Condition 2, the participant talked to the mock-up but received no response from it. Then she said, “You won’t say any, because you don’t know who I am.” Instead of considering about its malfunction, she seems to have inferred that the mock-up did not respond to her as she was a stranger. We hypothesized that seniors with dementia had strong tendency to imagine and complement missing information, which was caused by the deterioration of functions due to aging, and such imagination and complementation occurred positively by using Telenoid. Such tendency was found when interacting with the mock-up, which has neither voice nor motion. In Mock-up Condition 3, the participant held the mock-up upside down. We speculate that it happened because the complementation worked when the appearance was unclear to the participant, and she misunderstood that the head was on the other side.

In teleoperated condition, the participant answered the operator’s utterances and said, “One, two, one, two,” in accordance with the movement of Telenoid’s arms. There was a scene where the participant put her head to Telenoid’s head. It seemed that the movement of arms and head was easier for her to recognize. During the conversations, the utterances of the participant were unclear, so the operator sometimes failed to understand, and the conversations failed several times. However, the participant did not mind the conversations were not going well. She did not seem to understand the context clearly but did imagine something in her mind and kept the conversations.

We found that the participant had strong impressions and complemented images in her head. In Mock-up Condition 3, the participant hugged the mock-up upside down first. Even when caregivers pointed out that it was upside down, the participant did not listen to it and kept holding upside down. In Teleoperated Condition 2, the participant asked the name of Telenoid. When Telenoid said “I am Hiroshi,” she said, “That is wrong.” We speculate that the answer of the Telenoid did not suit the image she imagined. These images imagined by her became so strong that she could not accept the indication from others. It seems that we can hardly communicate with her without understanding her images and making ourselves agreeable to them.

We observed that the participant was interacting with both the mock-up and the teleoperated Telenoid respectively by imagining and complementing However, the average of utterance frequencies in the mock-up condition was less than the half of the teleoperated condition (Figure 4.7(b)). The participant was complementing but not motivated to talk. She tended to arrange the blanket covered over the mock-up, said, “Isn’t it cold?”, and patted its back. When she asked to call her grandma, she said, “You won’t say,” and kept interacting although there was no response. She seemed to recognize the mock-up as an infant or a child which cannot talk yet. She treated the mock-up like a baby, and the frequency of utterances were few maybe because she was trying to send the baby to sleep.

The participant imagined and complemented the mock-up, which has less information volume. Since the mock-up had no reaction, the image imagined by her was an infant or a child that was not supposed to talk. To motivate to talk, the image has to be someone who can talk. The mock-up had to have additional information so that it was recognized as a talkable person. In teleoperated conditions, the conversations were not understandable but the participant recognized it as the conversation partner. It seemed that reacting to the participant’s utterances was more important than the context of the conversation. Therefore a simple automatic answering system or being called by someone, such as “He is saying something” can make the participant recognize robots as a conversation partner. There was one scene where we did not use for the analysis; that is when the participant was sleeping in her private room before the dinner. A caregiver asked her to wake up but had fewer responses, so the caregiver tried to use the mock-up to wake her up. When the participant saw the mock-up, she immediately smiled and started to talk to it. The caregiver said, “He said he wants you to wake up,” and tried to wake her up. As the result, she woke up and headed to the dinner. In this way, by adding information to the mock-up by a third person, it is possible to raise motivation of the participant and to communicate.

4.4.4 Summary

We hypothesized that seniors with dementia would be motivated to interact with Telenoid because they tended to imagine and complement the lack of information positively by interacting with a simplified robot. We used a mock-up of Telenoid, which is a more simplified version of Telenoid, to reveal the relation between a senior with dementia and a communication medium with less information volume. We compared the interactions between Telenoid and the mock-up with the participant who had experienced interacting with the teleoperated Telenoid. As a result, we found that even a mock-up which had no information was able to interact with the participant by using imagination and complementation. However, the frequency of the utterances from the mock-up condition was lower than those from the teleoperated condition since the mock-up did not respond at all.

In order to motivate seniors with dementia to communicate, it is necessary for them to recognize that the medium is a conversation partner. Adding information by a third person or simple automatic answering system to react to the utterances may be useful to make seniors with dementia recognize robots as a conversation partner. In the middle of this experiment, one caregiver used the mock-up to communicate with the participant by adding information to the mock-up saying, “He said he wants you to wake up.”

The participant we observed had experienced talking to teleoperated Telenoid. Future work is required to consider more participants, including the one who had not interacted with Telenoid before. In addition, it is necessary to verify what kind of information can be added to the mock-up in order to be recognized it as a conversation partner and enhance the motivation of the seniors with dementia to talk.

4.5 Autonomous Dialogue System

Recently several autonomous dialogue systems are developed [2, 28, 68, 75]. However, most of such systems are based on textual corpora. These systems wait for the user to end the speech and then answer, which is different from face-to-face communication. In face-to-face communication, we sometimes interrupt the conversation partner’s utterance and talk.

Face-to-face communication involves transfer of nonverbal information. For example, if the conversation partner is smiling, we can estimate that the partner is happy. If the interlocutor looks bored, we can estimate that the current conversation is not interesting. We can understand whether the conversation partner agreed or not by looking into their eyes and behaviors, for example, nodding or not. We are expressing and estimating mental and emotional states each other to communicate.

When we failed to hear what the conversation partner said, we estimate from other clues, such as whether the partner agreed or not from their facial expressions. We complete lack of verbal information from the nonverbal information. When the conversation partner verbally agreed but had depressed facial expression, we can estimate that the partner gave grudging consent. Without reading the nonverbal information, we cannot understand whether the conversation partner is in bad mood or not, and may become impolite. Current autonomous systems involve such issues.

Most of current autonomous dialogue systems are based on textual corpora. They communicate using the result of voice recognition systems. Therefore, research about collecting textual dialogues, learning from databases, and improving voice recognition system is focused. However, actual environment involves noises from environmental sounds and multiple people talking, which makes voice recognition difficult. Even if voice recognition system becomes accurate, neither voice tone nor other nonverbal information is used in current systems to communicate.

Considering nonverbal information may cover the failure of voice recognition and other issues of an autonomous dialogue system. In this section, we propose an automatic dialogue system based on nonverbal information and estimation of mutual emotional and mental states. We considered following two items for the estimation.

- What kind of mental and emotional states are there, and how can it be updated?
- How can these states be used for the dialogue strategy?

The system is developed for seniors with dementia since they rely on nonverbal information to communicate and the context of the conversation is usually simple. Their interested level and emotional state are estimated by the system. Following sections will introduce the detail of the system and the case study of using the system in the elderly care facilities.

4.5.1 Communicate with Senior with Dementia

We focused on communication with seniors with dementia. In Japan, more than a quarter of the population is over 65. The number of elderly with dementia has reached over 4.6 million, and approximately an additional 4 million people suffer from mild cognitive impairment (MCI). This trend can also be seen globally [105]. Having a social connection decreases the chance of becoming dementia [14]. It is said that communication is important to have an appropriate care of the senior with dementia. However, the number of old age living by them is increasing and the opportunity to communicate with others is decreasing. In care facilities, a load of caregiver increases as the number of resident increases, and caregivers will have fewer opportunities to communicate with the residents. The communication support for the senior with dementia is needed worldwide.

Communicating with senior with dementia differs from ordinary conversation. The senior with dementia has low cognitive function due to the damage of the brain, and they sometimes repeat the same conversation. Seniors with dementia have Behavioral and Psychological Symptoms of Dementia (BPSD), which causes them to become depressed or offensive for example. The symptom of BPSD is not constant, therefore, it is necessary for caregivers to communicate and understand the current state of the seniors. However, it is difficult to communicate successfully with them.

Senior's speech may be unclear and the accuracy of speech recognition results low. However, it is possible to communicate nonverbally even if the accuracy of speech recognition is low in the proposed system.

Seniors with dementia have difficulty listening and seeing due to their age, and cognitive function declines. When they communicate in such condition, the information they received is partially lost and may fail to understand the context. Therefore, the lack of information is imagined and complemented. Seniors with dementia sometimes take a turn and communicate but talking about different things. In such conversation, they do not understand what each other are saying but both are guessing and misunderstood from the facial expression or the timing of utterance. Here, non-verbal information is used to complete the lack of information. Since seniors may receive less information, they become sensitive to the information they can sense. It is said that they become sensitive to the environmental sounds or facial expressions of the conversation partner. They rely on nonverbal information to communicate.

Seniors with dementia sometimes forget the person who met and what they talked about due to the short-term memory impairment. However, it is said that the feelings during the conversation remain. It is important to enhance positive emotions when communicating with seniors with dementia.

In this section, we introduce an automatic dialogue system implemented to a small version of teleoperated robot "Telenoid". Telenoid is a robot with a neutral appearance which can be teleoperated and move its neck and mouth [69]. From previous studies, seniors, especially seniors with dementia, favored interacting with Telenoid [69].

It is known that seniors with dementia talk to Telenoid using imagination [43, 44]. Although Telenoid cannot show facial expression, some senior said that it is laughing. Seniors with dementia treat Telenoid as a child or infant. Some even interact with a mock-up of Telenoid which cannot speak nor move. Telenoid motivates senior with dementia to communicate. The simple and neutral appearance of Telenoid might have enhanced seniors with dementia to imagine [43].

From previous works of seniors with dementia using Telenoid, we found that each senior individually has preferred topics to talk. They often repeat the favorite topics, such as their hometown or previous work. They might not prefer to talk about latest topics since short-term memory is impaired and cannot remember. It can be said that if each senior's favorite topics is prepared, limited contexts would be needed to communicate. Since seniors with dementia forget previous conversation and repeat same topics, fewer topics might be enough for autonomous dialogue system to be prepared.

In this section, we introduce a dialogue system based on mutual state estimation which focused on following 2 goals.

- Conversation for certain period of time.
- Enhance positive emotion.

These 2 goals are necessary from the caregiver's point of view. When the resident of an elderly care facility interacts with the robot with the proposed system for a certain period of time, the caregiver can focus on other tasks. In addition, BPSD, such as depression and disturbance, can be improved or prevented by communicating with the robot when a positive feeling is enhanced.

4.5.2 Estimation of Mutual Emotional and Mental States

4.5.2.1 Estimation of Emotional and Mental States

The purpose of this research is to develop an automatic dialogue system which positively motivates senior with dementia and communicates for certain time of period. Therefore, "interest" and "emotion" are focused as the internal state of the senior to be estimated. From the result of estimated state, the system will decide the behavior of the robot. For example, the robot will call and catch attention if the system detected that the senior is not paying attention or not interested.

The system includes estimated state and expected state of the conversation partner, and these states are compared to generate the response (Figure 4.8). For example, when the conversation partner is not paying attention when the speaker is talking, the speaker would say, "Are you listening?". In this case, the speaker expected the conversation partner to be listening. The speaker noticed that the partner is not listening, so the speaker tried to catch attention. It can be said that the behavior is made by such comparison of expected and estimated states.

4.5.2.2 Internal Emotional and Mental States

If the estimated state is same as the expected state, people may keep talking and feel good. In such case, the result of estimated state affects the internal state. People change their internal state by observing each other's state, and they mutually affect the internal state of each other. To implement this mutual estimation and change of internal state, it is necessary not only to estimate the internal state of the partner but also to express the internal state of the system by the robot.

It is thought that the internal state is influenced by various *desires*. For example, you may get irritated if you get hungry, and you may become less active if you are sleepy. When you want to tell a story, you might be motivated. By experiencing behavior coming from such desires, people learn the relation of behavior and desire. Then, we can estimate the conversation partner's internal state from their behavior. In this paper, we did not consider the desire and stated that the internal state is influenced just by the conversation partner to simplify.

People may feel better when the conversation partner is laughing, or feel bad when the conversation partner is depressed. That is, the internal mental state is influenced by the estimated state of the conversation partner. If there is a gap between expected and estimated state, people might feel uncomfortable. Our internal state is also influenced by comparing the expected and estimated states. We designed the model of mutual state estimation based on nonverbal information as Figure 4.8.

4.5.3 Experiment and Discussion

4.5.3.1 Experimental Environment

The robot with the proposed system was used to two residents with dementia from the special nursing home in Kyoto, Japan (Ms. A and Ms. B). The residents have already interacted with the robot and had shown a positive reaction to it. To investigate whether mutual estimation of nonverbal information is possible, we conducted an experiment with those who had shown a positive reaction to Telenoid in advance.

4.5.3.2 System

Russell's Circumplex model [80] which express emotion in two dimensions (arousal and emotional valence) is referred to the model of the internal state. We arranged "neutral" state for the boundary of the dimensions (Figure 4.9). When arousal is high ("joy" and "anger"), the system speaks faster and more often, and moves quickly and larger. When arousal is low ("sorrow" and "easy"), the system speaks slow and less frequently, and moves less and slowly. When the state is "joy", the system will look up and randomly play laugh voice. "Sorrow" state is described by looking down.

The degree of interest was measured by detecting face and estimating the emotion of the conversation partner. If the camera in robot's eye found the face, then the system notices that the senior is looking at the robot. The image from the camera is posted to Emotion

API from Microsoft Cognitive Services [53] to detect emotion from the facial expression. From the result of API, the interest level is determined. It is estimated as less interested if the conversation partner had low attention (less detection of the face) and showed less smile, and interested if had high attention level and showed smiling face frequently.

Emotion API from Microsoft Cognitive Services [53] is used to estimate the emotion of seniors. Figure 4.10 shows how sensor data is used for mutual estimation of the states.

8 topics (food, weather, etc.) with 5 to 10 speech are prepared for the conversation. For each topic, 9 to 21 related words were listed. The system determines that the senior is saying something related to the current topic when the result of voice recognition includes the related words (Figure 4.11). The system determines that the senior does not understand the current topic if the senior frequently says something not related the current topic and showed fewer smiles. If the system estimated that the senior is not listening, the robot repeats the utterance for the senior to listen and understand. If the system estimates that the senior is smiling and the related words are not included in the voice recognition result, the system determines that the system failed to recognize but the senior is saying something related to the current topic. We also prepared 8 kinds of simple QA including saying, "Hi." if the senior says, "hi".

The robot can move its mouth (open and close) and neck (tilt and nod). The robot nods when it is listening, and it tilts when it is not understanding or thinking for the reply. The mouth randomly moves and nods when the robot is talking. The magnitude and speed of the motion are related to the internal state of the robot.

Julius [47] is used for speech recognition and AITalk Co., Ltd. [119] is used to generate speech.

4.5.3.3 Result and Discussion

The trials for 2 participants (Ms. A and Ms. B) were conducted for 2 days. Each interaction was limited to the maximum of 30 minutes. If the participant shows no interest at all to interact or places the robot on the table, then the experimenter receives the robot and ends the interaction. On the first day of Ms. A, the experimenter gave the robot to her when she was sitting alone. She said, "You are cute," to the robot and started talking. She said, "It is heavy," after 12 minutes of interaction and placed the robot on the table. On the second day, the experimenter asked Ms. A to take care of the robot when she was sitting and had nothing to do. However, she said she was busy and denied to take care. Afterward, when the robot started to talk, she became interested, received the robot from the experimenter, and started to interact. She first started interacting with the robot including experimenter, then the experimenter left after 2 minutes of the interaction. After the experimenter left, Ms. A seemed like looking around trying to find the parent of the robot during the conversation. After 10 minutes of the interaction, she became less active and rarely responded to the robot. After 30 minutes, she talked to the caregiver walking by and said, “This child (robot) wants to sleep,” and placed the robot on the table. She left and the interaction ended.

On the first day of Ms. B, the experimenter asked her to wake up and take care of the robot when she was sleeping in the public room. When she noticed to the robot, she said, “So cute” and held it. She started to interact with the robot and said, “Cute”, however, she seemed like not listening to the robot. Ms. B sometimes reacted to the robot’s laugh and laughed. She held the robot and started to sleep after 6 minutes of the interaction. On the second day, she was sitting in a chair with another resident (Ms. C) and was asleep. When the experimenter carried the robot, Ms. C noticed and started to talk. The experimenter gave the robot to Ms. C, and she interacted for 11 minutes. After that, Ms. C woke Ms. B and gave the robot, saying, “(Robot’s name) got big.” Ms. B hugged the robot and started to talk; however, she was not opening her eyes and looked like she was sleepy. Ms. B interacted for 16 minutes and turned the robot to look at Ms. C. Then Ms. B started to sleep and never talked to the robot. Ms. C started to interact with the robot which was held by Ms. B. Ms. C sometimes said, “(You are) laughing.” After 27 minutes of the interaction, both Ms. B and Ms. C became quite and the interaction ended.

Trials for Ms. A and Ms. B started when they were not talking to anyone. They both seemed to be happy when they started the interaction. When the experimenter left, Ms. A may though of the robot being left alone and tried to find the parents. Ms. B started to sleep after the short interaction with the robot; however, the caregiver said that Ms. B often goes to sleep lately before the experiment. Therefore, it cannot be said that the robot made Ms. B sleepy. However, the system was not able to wake Ms. B up.

Both Ms. A and Ms. B were smiling when the robot was laughing, and Ms. B pointed out that it was laughing. It can be said that the state of “joy” expressed by the robot as an internal state was perceived by participants.

Also, when Ms. A looked away, the robot said, “Hi, grandmother” to catch attention, and the participant looked back to the robot. The system was able to detect the state of the participant not looking at the robot and was able to catch attention. However, Ms. B felt sleepy and fell asleep, so the system detected the low attention level but was not able to wake her up. Instead of just calling, the system needs other way to catch attention, such as talk about the interesting topic or speak louder.

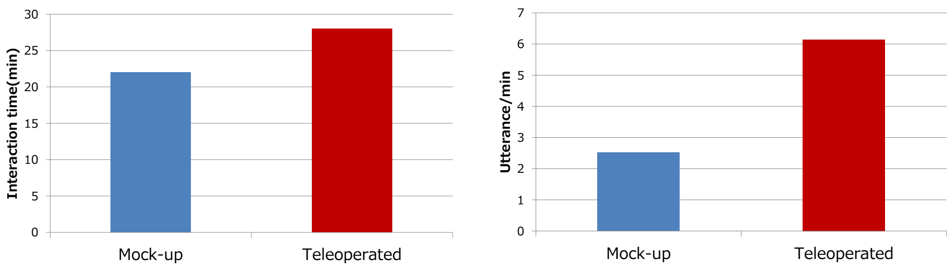
Further works include more participants to evaluate the accuracy of the estimated intention and emotion. We have to evaluate whether the internal state is expressed properly and seniors with dementia can sense it.

(a) Telenoid (left) and mock-up (right)

(b) Seniors with dementia interacting with Telenoid

Fig. 4.5 Telenoid

Fig. 4.6 The participant interacting with a mock-up of Telenoid



(a) Average time of interactions (min) (b) Number of utterances per minute

Fig. 4.7 Interaction time and utterances

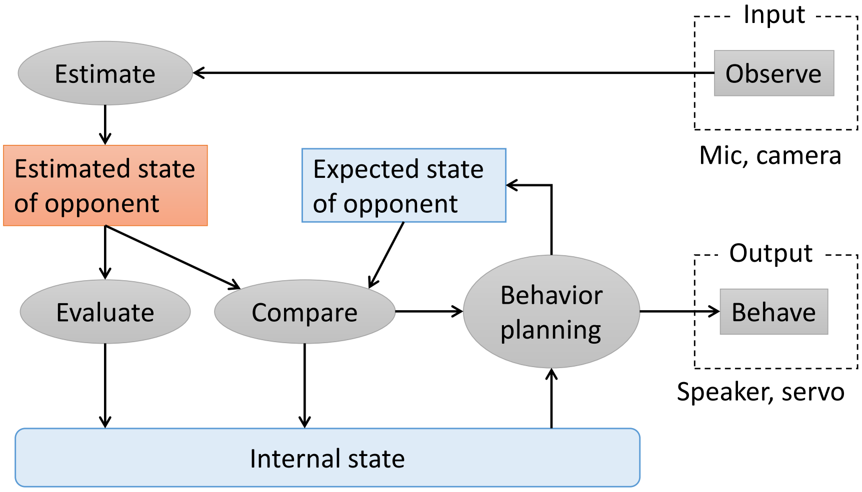


Fig. 4.8 Dialogue model based on mutual understanding: *The system obtains external information from camera and microphone to estimate the state of the conversation partner. The system compares estimated state with the expected state and generates behaviors. The internal state also influences the behavior. The behavior is expressed by gestures and utterances.*

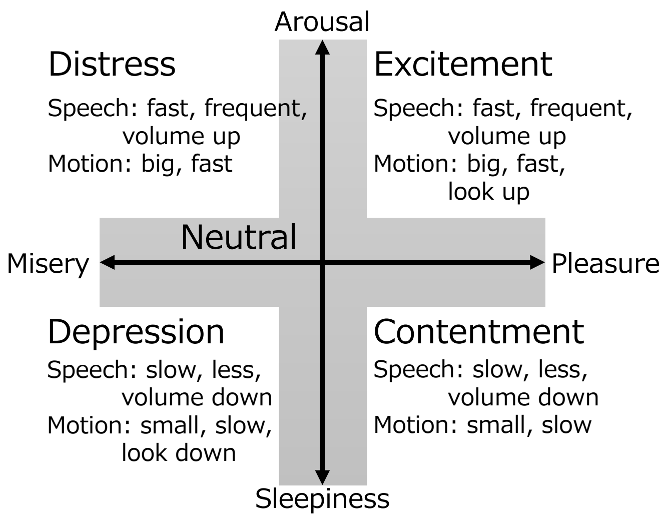


Fig. 4.9 Internal state model

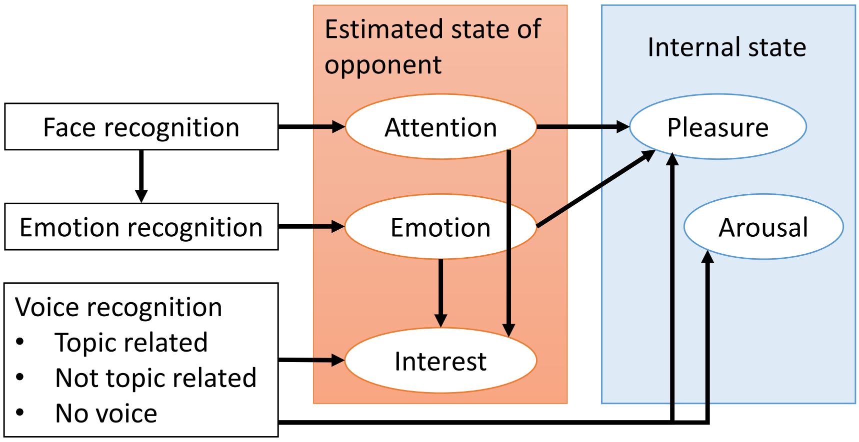


Fig. 4.10 Flowchart of mutual state estimation: *The result of face recognition is used to estimate the attention level. The result of facial expression recognition is used for the emotion estimation. The result of attention level and emotion influences interesting level of conversation partner, and the result of voice recognition influences interesting level and internal state.*

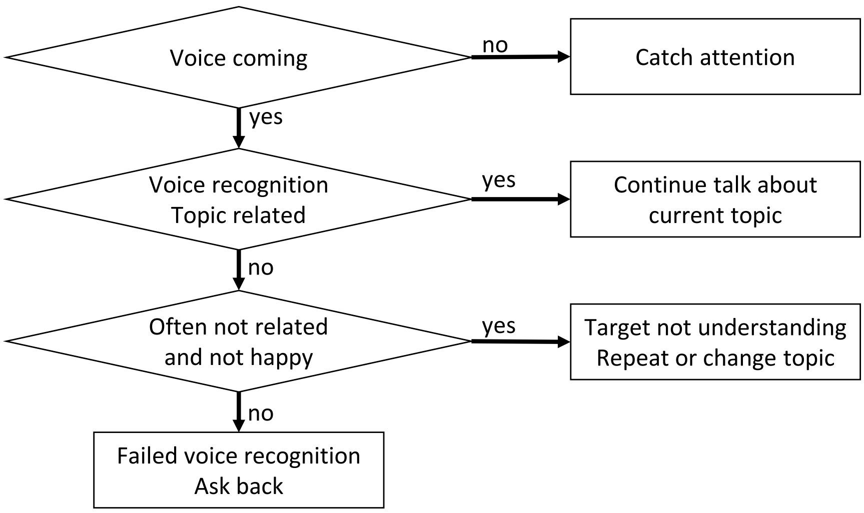


Fig. 4.11 Dialogue strategy

Chapter 5

Theory of Active Co-presence

Based on the results of Chapter 3 and 4, Chapter 5 discusses the theoretical perspective of how minimal-design robot influences the user's behavior. Unlike a detailed robot or video chat which transmits speaker's detailed information, a minimal-design robot transfers minimum information for interlocutors to imagine human presence. The amount of information transmitted is few, giving the interlocutors space to imagine. Instead of adding information, interlocutors can actively behavior in order to enhance the feeling of co-presence. We defined it the theory of active co-presence.

Robots for elderly care are meant to increase the quality of care services. We designed a teleoperated android called Telenoid to support communication with the elderly. At first sight, Telenoid's odd appearance often provokes negative reactions from people of various ages. After they hug and interact with it, their impressions become more positive. However, experiments in Japan and Denmark suggest that the elderly easily accept Telenoid from their first interactions with it, but the reason remains unexplained. This paper hypothesizes and discusses possible reasons why Telenoid is accepted by the elderly. We think that Telenoid triggers and enhances the ability of the elderly to imagine and positively complete the information, thus making them feel attracted to it. Based on this hypothesis, we discuss the factors that trigger the imagination and lets the senior citizens form a positive impression of the robot.

5.1 Robot for Positive Communication

Japan's elderly population continues to grow rapidly, and the total exceeded 30 million in 2012 (The white paper on the aging society). Almost a quarter of Japan's population is over

65. The number of elderly with cognitive disorders is about 4.4 million, and over 3.8 million suffer from mild cognitive impairment (MCI). These numbers indicate a serious problem.

Research is focusing on robots that support caregivers and the tasks they must perform, including a caring bathtub and power-assisting suits [21, 59, 74, 94]. Several robots have been built that physically assist seniors. Introducing such robots to care facilities will increase elderly autonomy and reduce the burden on caregivers. However, caregivers also have to be concerned about the psychological issues regarding the elderly. Since the elderly often have limited social networks, increasing their risk of dementia [14], conversation is important to avoid or lessen dementia, and to decrease anxiety, which suppresses the behavioral and psychological symptoms of dementia (BPSD). Since caregivers often have little time to communicate with residents of elderly care facilities, robots which encourage the elderly to communicate and reduce the mental burden are needed.

Some robots provide the elderly with an opportunity to communicate [42, 69, 108]. Kuwahara *et al.* developed networked reminiscence therapy, which effectively increases the self-esteem of, and reduces the behavioral disturbances in individuals with dementia [42]. Their system combines IP videophones with a photo- and video-sharing mechanism. In their experimental results, dementia sufferers communicated with therapists by videophone, and networked reminiscence sessions were generally as successful for individuals with dementia as face-to-face reminiscence sessions. However, the elderly may not feel encouraged to use such communication tools as phone or video chat.

Perhaps the most famous communication support robot is Paro, a seal robot designed for therapy [108]. Paro has sensors on its body and reacts with sound and several actuators. More than 1500 Paros have been sold in Japan. Its cute appearance and behavior stimulates the interest of the elderly. Unfortunately, it is not designed for verbal communication.

We designed a teleoperated android called Telenoid to support communication with the elderly (Figure 2.1). In our previous research, we observed unique reactions in the interaction between the elderly and Telenoid. At first sight, its odd appearance often provokes negative reactions in people of various ages. After they hug and interact with it, their impressions become more positive (Figure 5.1) [69]. However, experiments in Japan and Denmark suggest that the elderly easily accept Telenoid from their first interactions with it. Some even became so attached to it that they refused to release the robot. For example, when a care worker operated Telenoid in a day-care center, all of its elderly gathered around it, hugged it, and talked to it from the beginning.

From experiments in Japan and Denmark, we learned that senior citizens are immediately

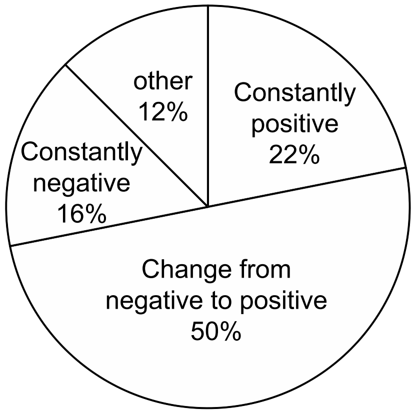


Fig. 5.1 Impression of Telenoid after interaction

interested in Telenoid, from the beginning of their interaction with it. Telenoid encouraged active communication in the elderly with mild dementia and physical interaction from those with severe dementia [113, 114]. When a care worker operated Telenoid at a care center, all of its elderly patients gathered around it and hugged and talked to it without waiting for any explanations. Our questionnaire results indicated that more than 90% of the elderly who talked with Telenoid enjoyed their experiences. Some even cried because they felt they were talking with their children or grandchildren. When asked to choose between Telenoid and a cellphone for communication, around 60% indicated a preference for Telenoid [69].

During their interaction with Telenoid, the elderly with cognitive disorders often treated it like a baby or a child. Even if Telenoid's operator is a care staff member, they treated it like a baby. Some re-named it and provided imaginary hometowns, etc. for it. Some became so attached to Telenoid that they lost interest in others. One day, the caregiver gave a Telenoid mannequin with the same appearance and weight to a resident who woke up in a bad mood. After getting Telenoid, the resident smiled, began to talk, and her mood improved. The caregiver was able to get her out of bed and into a wheelchair. Some residents even became attached to the fake Telenoid, and their behavior improved. Others were saddened because the fake Telenoid was not moving. Some told the caregiver that Telenoid urinated when they saw it move. Such reactions indicate that these senior citizens believe that Telenoid is alive. However, the reason for such a belief or why Telenoid is so captivating remains unknown.

Some elderly reacted positively toward Telenoid, which often surprised care workers, such as when a person suffering from depression became loquacious. Although Telenoid is warmly accepted by some elderly with cognitive disorders, others reacted negatively toward it and showed little or no interest in it. Others initially had no interest, but later became interested and increased their interactions with it. In some elderly, their interest level fluctuated.

5.2 Why is Telenoid Accepted by the Elderly?

Some elderly carry dolls and enjoy taking of them. When we concentrated on the interaction of the elderly who are attached to Telenoid, we found that most treated it like a baby or child, smiling at it and playing games like peekaboo. The elderly interacting with Telenoid often react as they would to a doll. Its size and weight might trigger connections to babies. However, we do not understand why Telenoid's appearance and size is so attractive for seniors. Some elderly who dislike children did not hesitate to talk to Telenoid. We focused on how they receive and recognize external information to understand why Telenoid is accepted by the elderly, especially those with cognitive disorders, by focusing on senior cognition.

5.2.1 Cognitive Function for the Elderly with Cognitive Disorders

As we age, our senses become less acute. It becomes more difficult to see and hear. Cognitive functions are reduced even further when people suffer from cognitive disorders. Therefore, the elderly with cognitive disorders fail to receive some or most external information. How can they communicate with others? We hypothesize that they are completing the information missing from their mind using their imagination. Some phenomena support this hypothesis. Sometimes, the elderly with cognitive disorders have conversations with each other. However, they seem to talk about different things. For example, one talks about the weather and the other talks about lunch. During such conversations, they are taking turns and nodding in response to what their partner is saying. Yet they do not seem to hear or understand what the other is saying. However, they are having a conversation. They seem to guess what the other is saying and continue their conversation. They are completing the information that is missing from what they received and guessing about the rest. Since they have lower cognitive functions, they misunderstand what the other is saying.

Such completion of missing information can be seen in daily life. For example, when talking on the phone, we might imagine the speaker's identity or appearance based on their voice. Since a telephone only transmits the voice, the user receives limited information and must infer the missing information.

Even though the modalities used for communication are quite limited, we can imagine and complete the images. When we meet face-to-face, our imagined perception is proba-

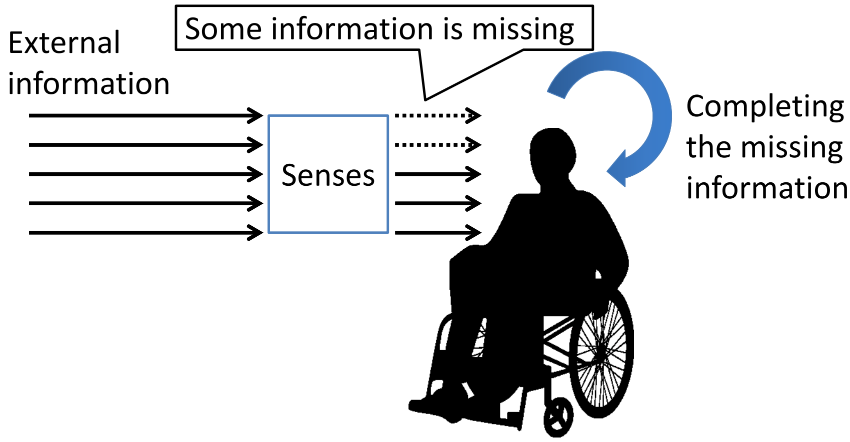


Fig. 5.2 Cognition model in senior citizens

bly different from the resultant reality. The image we imagined might be different from the original person. During several long interactions, our brains will calibrate the image. Seniors with cognitive disorders fail to calibrate correctly, because their cognitive functions are dulled. We believe they treat a doll as real and have inconsistent conversations because their calibrations fail.

Despite lower cognitive functions, the remaining senses of the elderly with cognitive disorders seem to become more acute. Since they cannot recognize their environment very well, they concentrate on other senses and become sensitive to the information they receive. As a result, the elderly with cognitive disorders overreact to what they sense and are overly sensitive to the facial expressions and the noises made by others. Some seniors with cognitive disorders have BPSDs and mistrust caregivers and family members and complain about them. They might imagine that something was stolen from them if they see someone carrying a bag or touching something.

5.2.2 Design of Telenoid

Telenoid's appearance is designed to be neutral, without specific characteristics. Its limited actuators represent the minimal behavior for a conversation. By teleoperating and talking though Telenoid, teleoperator's behavior and characteristics are limited. Those who interact with it also have limited visual information about the teleoperator. Since people usually rely most heavily on their sense of sight, sight can induce illusions about the other senses [23, 57]. Because Telenoid reduces users' reliance on their sense of sight, the other senses, which are normally used less often, become more necessary, and affect their perception.

Telenoid's design triggers the user's imagination. Since the elderly and those with cognitive disorders complete the missing information more often, Telenoid seems to be easily accepted.

5.2.3 Physical Interaction with Telenoid

Those who interact with Telenoid enjoy such physical interactions as touching, hugging, patting, and kissing it. Physical interaction increases when people are in good relationships, especially hugging, which provides relief and is used for remote counseling [56]. Hugging also allows users to intimately hear voices during physical contact. With Telenoid, users can hug and talk as if they are near each other. Those interacting with Telenoid are under the wrong impression that they have a good relationship with it.

5.2.4 Other Aspects of Telenoid

Seniors who talk to Telenoid appear willing to talk more in daily life. Those who complain to Telenoid about their caregivers or their facility are dissatisfied in daily life. Since they might suppose that Telenoid is living in similar circumstances, they feel sad that Telenoid is staying in the same facility.

The elderly seem to take the missing information from their environments and their mental states to complete their imagined view of Telenoid. To have a positive impression about the robots, users should probably be in a good mood; we should arrange environments where users can relax. To design a robot that positively impresses interlocutors, the user's environment and mental states have to be considered.

5.3 General Method

Based on Section 5.2, we may say that Telenoid positively affects elderly imagination for the following reasons:

- Telenoid's plain design does not rely on visual information and stimulates the user's imagination.
- Telenoid's users hug it and experience physical interaction that stimulates tactile and other senses as well.

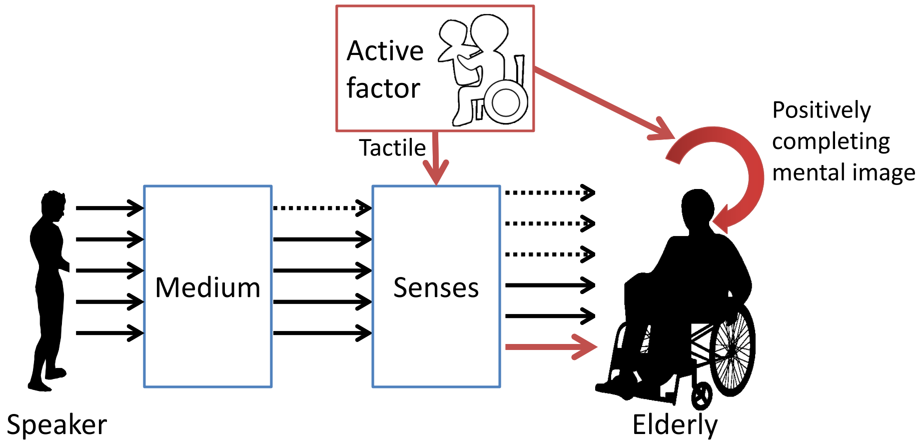


Fig. 5.3 Enhancing a copresence model

Since a user who is facing Telenoid cannot know the teleoperator's appearance, Telenoid limits the reliance on vision of the users, forcing them to rely on other senses. By physically interacting with Telenoid, they sense it tactilely. Moreover, since its appearance is plain, users can easily reflect their imagination on it. By adding factors that positively complete the image (in this case, physical interaction), Telenoid gives a positive impression to users (Figure 5.3).

The elderly, especially those with cognitive disorders, seem to complete the information missing in their mind more often than ordinary people. Therefore, such a medium is effective because it positively affects the user's imagination. When a robot is not designed with active factors that elicit positive impressions from the elderly, perhaps they imagine and feel negatively toward the robot. They might be afraid of it. Once they fear it, it is difficult to introduce it to the facilities. A robot that interacts with the elderly needs a design which encourages them to use it. Reliability and comfort are required for a robot which corresponds to the needs of the elderly. By adding factors that create positive impressions (Figure 5.3), the elderly have a positive impression of the robot.

In previous research that compared a medium that only transmits voice, hug behavior toward the medium (*e.g.*, a pillow) enhanced the speaker's presence and feelings of being loved [45]. The user's hug behavior became a positive factor that influenced and completed the user's imagination. This result also indicates that impressions based on imagination can overcome the original, negative impressions. Future work will investigate which factors are more effective for the elderly to imagine and complete the missing information.

Since our design relies on the imagination of the elderly, their mental state has to be carefully considered. When they are in a bad mood, a robot's image might be completed negatively. However, when properly using a robot with positive factors, the mood of the elderly might improve. Using a robot also has to be well considered by its handlers, such as the caregivers. When introducing Telenoid to a new care facility, we first have information sessions for the caregivers and the staff. This process is crucial for the successful use of a robot in care facilities.

5.4 Summary

Previous research indicated that the elderly, especially those with cognitive disorders, react positively to Telenoid. However, the reason remained unexplained. We focused on the cognition of the elderly with cognitive disorders. They have low cognitive functions and dulled senses due to their age. During communication, we believe that they have to imagine the missing information. We hypothesized that Telenoid triggers and enhances the imagination of the elderly and helps them positively complete the missing information; this is why they are attracted to it. Based on our hypothesis, we further discussed the factors that trigger the imagination that completes the positive impressions of robots for elderly care. Even though many robots that support the elderly have been invented, both their practicability and their design need to be further considered. Especially the cognitive function of the elderly must be taken into account to produce a design that they want to use.

Chapter 6

Conclusion

Overall motivation of this study is to have a better communication by using telecommunication media. The focus of the study is to make a positive impression of the speaker to promote the interactive eagerness of the user. This thesis hypothesized that positive impression can be fostered by "less information" and "physical embodiment". A minimal-design robot is used as the communication medium to test the hypothesis. Chapter 3 examined behavioral changes found when interacting with a minimal-design robot. In Section 3.2, Telenoid with non-human like appearance robot and video chat were compared to reveal the effect of minimal-design appearance and physical presence. The result shows that the conversation partner can receive consistent personality of the speaker talking from the minimal-design robot and can feel appropriate atmosphere related to the condition. In Section 3.3, the effect hugging communication medium was examined. The result shows that the participants enhanced the feeling of co-presence and being liked or loved by hugging. Section 3.4 discussed the result found in Section 3.2 and 3.3. Telenoid and Hugvie are designed to have a neutral appearance for anyone to use. These media have minimal information to feel the human presence. Conversation partner interacting with the minimal-design robot cannot identify facial expressions and detail of gestures of the speaker. However, in Section 3.2, by mediating Telenoid and limiting information instead of using video chat which has a large amount of information, the conversation partner can perceive the appropriate atmosphere related to the condition. In the experiment using Hugvie in Section 3.3, it can be said that participants less hesitated to hug since the amount of information are limited by mediating Hugvie. The user's feeling of being liked or loved when talking via Hugvie is fostered by misattribution of the behavior of hug. Such positive impression is enhanced such robot with restricted information has more space to imagine compared to a detailed robot or the original person talking face-to-face.

From the results, the theory of active co-presence which encourages a positive impression of the speaker and promotes communication was proposed. By restricting the information to be transmitted, we can encourage the user to imagine and complete, however, the amount and quality of information transmitted matters to complete positively or negatively. In experiments using the mock-up of Telenoid in Section 4.4, in the case of mock-up, when no speech is produced, the interaction was performed, but the amount of utterance of the user decreased compared to the normal Telenoid. This was because the mock-up said nothing which causes the participant to imagine a baby. The information can be limited to enhance imagination, but there need verbal information or some other information which allows users to imagine someone who can talk, in order to promote communication. The behavior of hug is focused as an element of imagining positive impression, and other factors such as quality of voice and gesture can be considered in future works. Future works include investigating elements which positively affect users and further discussion of the theory of active co-presence.

The communication support of the seniors with dementia is focuses as the application of using imagination for a better communication; however, there are other applications, such as communication support of school children or autism children [63, 87]. Recently, there is a tendency to integrate various communication media (unified communication: UC) in order to enrich information for telecommunication, including the development of human-like androids, such as Geminoid. However, instead of the enrich information, limited information encourages users to imagine and complete to have a positive impression and promote communication. The minimal-design robot limits the information of the speaker, and by physically interact with it, users can imagine positive impression and result to the better communication.

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