Adaptive and Expressive Social Mediator Robots That Facilitate Remote Communication Between Humans

March ２０２２

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Acknowledgements

I am grateful to my supervisor, Dr. Fumihide Tanaka who made this work possible. His passionate guidance and advice supported me in all stages of my project. I would also like to thank the members of the dissertation committee for giving me the opportunity to present my dissertation and for their constructive and brilliant comments. In particular, I would like to thank Dr. Hiroko Kamide, with whom I have collaborated for a long time since I was a student in the master's program, for her great cooperation.

Also, I would like to thank the former and current members of the Fumihide Tanaka Lab. Fruitful discussions with them have contributed to my research project. In particular, I would like to thank my oldest friend, Denis Pena. I have gained many insightful ideas from the discussions with him, thank you very much.

Lastly, I would like to give special thanks to my parents and my family as a whole for their continuous support and understanding my research and writing my project. I would also like to give special thanks to my friends outside the university, especially my friends from Miyazaki Nishi High School. Their friendship and encouragement has helped me a lot, thanks to you.

This work was supported by following founding sources:

- JSPS KAKENHI Grant Number 15H01708 and 19H01112
- Grant-in-Aid for JSPS Research Fellow Grant Number 20J10887
- Grant-in-Aid for Scientific Research on Innovative Areas Grant Number 20H05553

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Chapter 1

Introduction

1.1 Research Background

In modern society, many people are living away from their family members and friends due to work, study, or other obligation. Lack of daily communication may increases the sense of loneliness, and sometimes this can be the cause of a severe mental disease. Meanwhile, text messaging devices such as mobile phones brought huge benefits to our remote communication in the last three decades. The advent of these devices has made people's remote communication become instant. Nowadays, these devices are commonly used to communicate with family members and friends who are in remote place. Furthermore, compared with other classic devices based on typing, modern devices with voice recognition capabilities provide a more efficient message creation process to users (such as smart speakers).

As the extension of text messaging devices, the use of social robots as a remote communication interface between humans has recently been proposed (Fig. 1.1). In this framework, the social robots placed in each house are connected via the Internet, and humans can exchange their messages through the (mediator) robots. Recent advancement in speech recognition technologies brings easier message creations than the past. Although still more improvements are needed, they are particularly welcomed by users who feel stress in key-typing. In fact, some of the mediator robot have already been introduced to the market as commercial products. For example, RoBoHoN, developed and distributed by SHARP, a major Japanese consumer electronics manufacturer, is a small humanoid robot that mediates human messaging via robot behaviors, such as gestures and speech dialogues [25]. Also, in 2017, NTT docomo, one of the largest telecom companies in Japan, launched Communication Partner Kokokuma, a stuffed toy that mediates messaging between

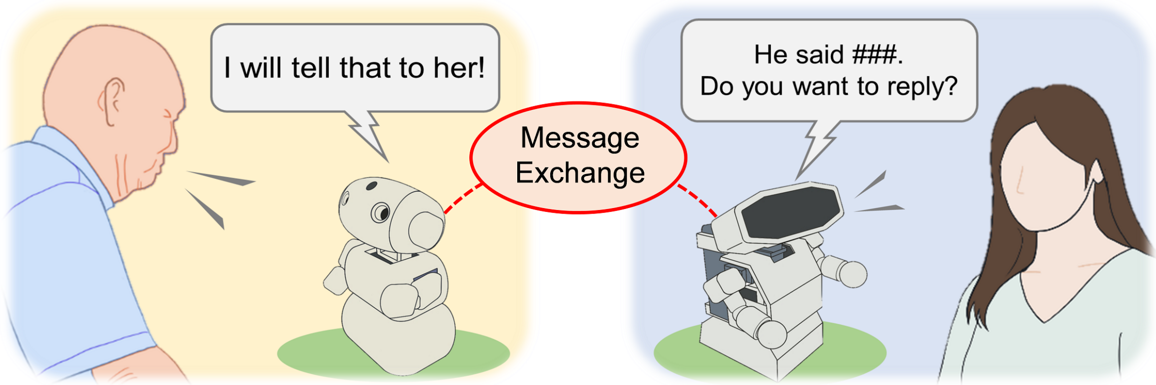

Fig. 1.1 Social mediator robots: robots connected via the Internet serve as mediators, and humans can exchange their messages through the robots. In this example, the elderly user who live separately from their family members or friends is assumed, and both sides use the robots to exchange their messages.

elderly people and their family members living apart [161]. Furthermore, some local governments have already begun to incorporate these robots into their public elderly care services: for instance, the city of Saijo in Ehime Prefecture, Japan, launched a robot rental service for elderly households in 2019 [23].

1.2 Limitations of Conventional Mediator Robots

The use of social robots as messaging interfaces will enhance the convenience of remote communication and is expected to become one of the new standards in our communication, as more and more robots become widespread in our society. Furthermore, social robots that emerge in the future should also have the ability to facilitate social relationships between two users by intervening in human communication. For example, if a mediator robot that can display appropriate behaviors based on the personality traits of each user, it could encourage the user to disclose even in the topics that are hard to tell to the other user directly. Also, a mediator robot that can switch its behaviors when it delivers a message, the awareness of the recipient user will be successfully modulated (e.g., if a robot emphasize its serious attitude during reporting the message, the recipient may listen to the message more seriously).

However, we still do not know how the robot should behave in each of the situations where it mediates human communication. Specifically, the behavior of social robot that actively intervenes in human messaging, as in the example above, is still unexplored. Thus little knowledge is available with respect to the design guidelines. In order to realize a mediator robot which truly works as an effective third party assisting humans in building interpersonal relationships, at least, the following limitations in conventional robots must be overcome.

Firstly, there is a lack of experimental data for the feasibility of the use of mediator robots on human communication. Although mediator robots have already been introduced into society as commercial products, their impact has never been measured from a scientific perspective. In order to design an effective mediator robot, the design guidelines should be discussed based on those measurements.

Secondly, adaptive interaction has not been designed in mediator robots. In the filed of Human-Robot Interaction (HRI), design of user-adaptive interactions has been regarded as one of the key elements for developing an intelligent social robot. If a robot can adjust its behavior using the user's information, it will be able to personalize the interaction and the user will evaluate the robot positively [94]. However, RoBoHoN and other conventional mediator robots only could read out messages and do not provide any of the modifications to its behavior according to the information such as topics of the message and/or the property of the users (e.g., gender, personality traits, etc.). This will make it hard to sustain users' interest in the robot.

Lastly, expressiveness of mediator robots needs to be enhanced to convey human messages effectively. Most conventional mediator robots use speech dialogue as the primary expression channel during the interaction with the users. However, communication capability of these robots remains insufficient in many aspects. Numerous studies have shown that people lose interest in their robots after the novelty effect disappears. The RoBoHoN was also reported to be unable to sustain users' interest [108]. Overall, the manner in which the robot's messages are delivered tends to be *flat*, and people quickly lose interest. This can be a fatal problem when the robot has to convey some important messages to the recipient. In HRI, many social robots are designed to convey their internal states not only with speech but also through nonverbal signals. To date, as the nonverbal expression in robots, facial expressions [49, 162] and body movements [101] are majorly discussed. Recently, as a new trend in HRI, the use of haptic signals in robot expression has been proposed, such as skin temperature [106, 122, 14] and skin texture [62]. Literature suggested that haptic stimuli generated by a robot may be dominant in human emotion perception compared to visual signals such as facial expressions [123]. However, non-verbal expression channels, especially those with haptic signals, have not been discussed in mediator robots. Therefore, a novel hardware needs to be developed, to test the effects of non-verbal (haptic) expressions of mediator robots in human messaging.

1.3 Research Objectives

Through overcoming the above limitations, this research aims to design an adaptive and expressive social mediator robot that facilitates remote communication between humans. This research attempts to provide pioneering insights into design guidelines that did not exist before, through the development of robot prototypes, user studies, and large-scale online surveys. Specifically, this research was conducted in accordance with the following objectives.

- **Objective 1**:
  Presenting experimental evidence for the feasibility of mediator robots that support remote communication between humans
- **Objective 2**:
  Exploring behavioral design guidelines for mediator robots to bring about adaptive interaction
  - (2a) Development of a method to match the personality traits of the mediator robot according to the message topics and the sender's profiles
  - (2b) Development of a method to switch the behavior of the mediator robot in reporting messages to the recipient according to the sender's preferences
- **Objective 3**:
  Enhancing the non-verbal expression channels of mediator robots to influence the perception of message recipients
  - (3a) Development of a novel hardware of mediator robot that could present haptic expressions
  - (3b) Examining the influence of the haptic expressions of a mediator robot on human messaging

1.4 Overview of the Dissertation Content

In Chapter 2, by comparing with related works, the concept of social mediator robot will be stated. This research is relevant not only to the field of HRI (and HAI: Human-Agent Interaction), but also to the study of CMC (Computer-Mediated Communication). The important literature in each research field will be presented, and the contributions of this research will be described.

From Chapter 3 to Chapter 6, messaging between the elderly people and their family members is assumed. Social isolation in elderly people is becoming a serious issue in many countries. It is particularly the case with the elderly who live separately from other family members. Also, it should be noted that elderly people often do not reveal their true emotions easily [92, 27]. Even if they are facing serious troubles such as health or financial problems, it can be difficult for them to disclose the troubles to others and request supports. In order to prevent the elderly people from being socially isolated, technological supports should provide them with a smooth communication capability with other people while encouraging their self-disclosure. However, self-disclosure has never been studied within the framework of a mediator robot, thus the relationship between robot behavior and the elderly self-disclosure, is still unexplored. Therefore, we conducted several studies described in the corresponding chapters below.

In Chapter 3, the relationship between the robot's specifications and the topics in which the elderly people are encouraged to self-disclose is discussed. After the development of a prototype robot, through an HRI study using the prototype (N = 21), the effect on self-disclosure of the elderly was studied.

In Chapter 4, effective personality traits of social mediator robots according to the message topic, the gender factor, and personality traits of the elderly user is discussed. A large-scale online survey (N = 720) was carried out to obtain the detailed design guidelines of the robot. The results provided more detailed knowledge as to similarity-attraction/repulsion than had been previously reported. Finally, design recommendations were discussed, by considering the personality traits of the elderly users, too.

In Chapter 5 and 6, the relationship between the robot's behavior in conveying messages to the recipient and the anxiety perceived by the elderly users when they make self-disclosure is discussed. If the mediator robot can provide a preferable option for the elderly users to assist their self-presentation, perceived anxiety might be suppressed. Three phased online surveys with a total of N = 1248 participants

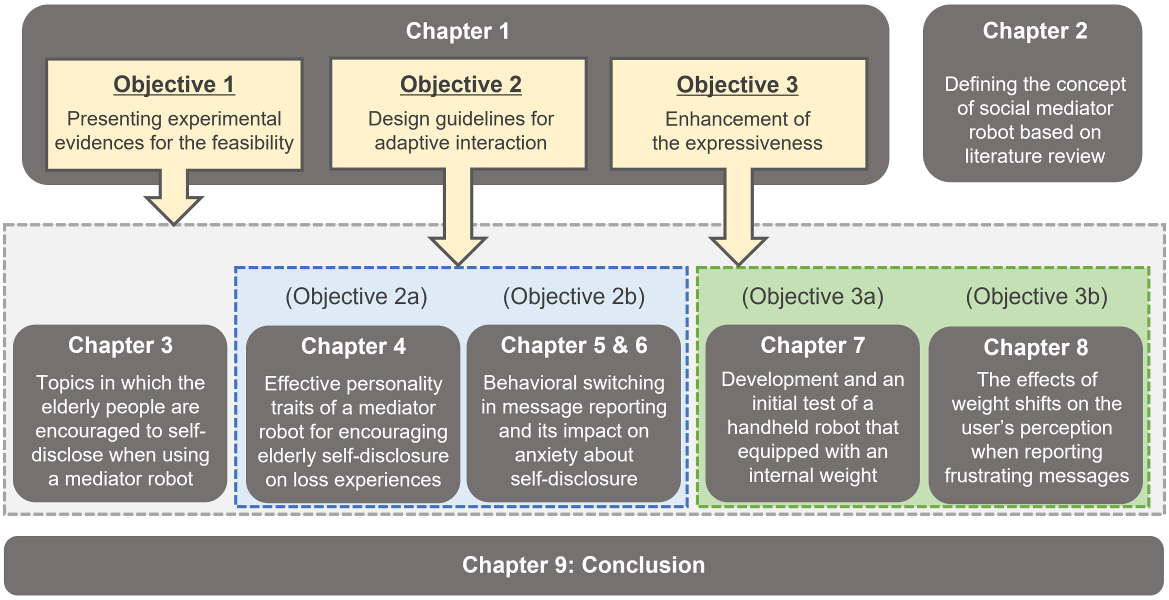

Fig. 1.2 Overview of the content of the dissertation

were conducted to develop appropriate behaviors of robot in reporting messages (Chapter 5). After that, an HRI study (N = 36) was carried out by using a robot, to which the developed behaviors were implemented (Chapter 6).

In Chapter 7 and 8, a messaging situation involving two young persons is assumed. More specifically, a mediator robot tries to intervene human interpersonal conflicts. Studies on CMC revealed that the users' hostile, aggressive, and uninhibited communicative behaviors, called flaming, were more frequently observed in text messaging than face-to-face and videoconferencing e.g., [83, 75, 119]. To maintain healthy interpersonal relationships by reducing the user's aggressive behaviors, a mediator robot should be designed so that it can suppress the user's anger and other interpersonal motivations (e.g., revenge and avoidance motivations). However, from this viewpoint, the introduction of mediator robot has never been explored.

This study investigates the behavior of a mediator robot that is particularly effective for users receiving frustrating messages from other people. An HRI scenario was assumed in which a robot verbally gives its opinion to such users while expressing non-verbal signals. As the non-verbal expression modality of robot intervention, we focused on a haptic-based interaction channel using internal weight movements (weight shifts). To this end, a handheld robot, called OMOY, equipped with a movable weight actuated by mechanical components inside its body was developed. Through the weight shifts, the robot expresses its emotions and intentions to the user holding it. Furthermore, using weight shifts to communicate may influence the users' social judgments and decisions. Following psychology literature suggesting that the abstract concept of importance is grounded in bodily experiences of weight [67], recognized importance of robot's speech contents may be enhanced when the users feel heaviness in weight shifts.

In Chapter 7, the hardware specifications of OMOY is described. OMOY presents weight shifts by controlling the internal weight based on four movement parameters, such as target position, trajectory, speed, and repetition. In addition, an elicitation study (N = 18) was also reported, which was conducted to investigate how users interpret various weight shifts. Results present mappings between these parameters and the emotional perception of the users. Furthermore, specific weight shift patterns that can express certain human emotions and intentions are revealed.

In Chapter 8, the effects of weight shifts on the human messaging were discussed. In a controlled study (N = 94), in which participants were manipulated to be frustrated by using a context scenario, we studied the effect of three dialogue scripts with/without weight shifts. Results showed that introducing weight shifts together with the robot speech has significant effects in which the user's aggressive mind got to be suppressed (e.g., on average 23% of the user's anger was suppressed).

The final chapter, Chapter 9, summarizes the key findings from these studies and discusses the future prospects for research on social mediator robots. Fig. 1.2 summarizes the structure of this paper.

Chapter 2

Social Mediator Robot

This chapter presents a review of the literature in related research fields. Doing so, the scope of the contribution of this study can be clarified. In addition, based on the previous knowledge, I also attempt to conceptualize the social mediator robot that is discussed in this research.

2.1 Conceptualizing Social Mediator Robot

2.1.1 Computer-Mediated Communication

Interpersonal communication via social mediator robots can be regarded as a subordinate concept of Computer Mediated Communication (CMC), which is generally defined as “communication that takes place between human beings via the instrumentality of computers” [160]. In the context of CMC, researchers have explored a wide range of the social effects of communication between people using network-connected digital devices to exchange messages (e.g., text messaging, social network site interactions, videoconferencing) [160]. Among the CMC channels, text messaging has been majorly studied because of its unique features attributed to the limited non-verbal information for exchange and asynchronicity [166, 66]. For example, as numerous numbers of researches suggested, self-disclosure of human tends to be encouraged in CMC [66, 100], particularly under a condition in which the effect of nonverbal cues is small.

2.1.2 AI-Mediated Communication

Recently, Hancock et.al. conceptualized artificial intelligence-mediated communication (AI-MC) as a modern extension of CMC and envisioned it as a possible future communication style for humans [48]: defined as *"interpersonal communication in which an intelligent agent operates on behalf of a communicator by modifying, augmenting, or generating messages to accomplish communication goals."*

In [48], several examples of AI-MC systems already available in our devices are shown. First of all, Gmail smart reply allows the recipient of an email to choose one of several AI-generated replies. In this system, generally, the involvement of the AI is not revealed, and the recipient assumes that the message was created by the sender him or herself. Moreover, emerging AI-MC systems that can provide further optimization to messages according to the recipient were also introduced. For example, Crystal that can inform a sender about "how [the recipient] wants to be spoken to" based on the recipient's social media profile [28].

In response to the emergence of these AI technologies, recently a lot of of researchers have started to investigate the impact of the AI on people's social interactions and interpersonal relationships, by mostly using an AI-MC system similar to the Gmail smart reply. For example, Hohenstein et.al. reported that presence of AI-generated smart replies serves to increase perceived trust between human communicators. In their study, the conversations took place under conditions where the AI-MC system generated specific options for replies through the messaging interface, so the participants were able to recognize the presence of the AI. In such a case, when things go awry, the AI seems to be perceived as a coercive agent, allowing it to function like a moral crumple zone and lessen the responsibility assigned to the other human communicator [58]. In [58], the focus is mainly on the psychology of senders using AI-generated messages, but some studies have investigated the impact of AI-MC on recipients' side. For example, Mieczkowski et.al. found that AI-generated language has the potential to undermine some dimensions of interpersonal perception, such as social attraction [98]. Since the options for a response generated by current AI-MC system in messaging platform tend to be more emotionally positive than negative or neutral [57], the recipient's expectations of a typical conversation seen to be violated [98].

An important feature of AI-MC system like Gmail smart reply is, again, the ambiguity as to whether a given message is human-generated, AI-generated, or a composite of the two. Since users prefer to reduce uncertainty in their interactions [12], this lack of transparency about the impact of AI is considered to play a role in increasing uncertainty and negatively impacting perceptions of trust [57, 58]. Although these studies on AI-MC are still in the early stages and are expected to be discussed in the future, further discussions on AI that "pretends to be a human user" seems necessary from an ethical perspective [48].

On the other hand, in AI-MC research to date, little consideration has been given to the perception of personality towards AI agents. In other words, previous researches on AI-MC have lacked the perspective of actively utilizing the fact that humans tend to anthropomorphize artificial entities [32]. Instead, the use of AI agents as third parties (mediators) can be expected to avoid the ethical concerns of AI-MC mentioned above and to have a complementary impact on human communication.

Thus, following the AI-MC concept [48], the social mediator robot discussed in this study can be conceptualized as follows: *"an intelligent agent that intervenes in human messaging by modifying, augmenting, or generating messages to accomplish communication goals, and is explicitly presented to the communicator as a third party."* This concept based on the assumption in which the users perceive human-like personality from the agent [32]. In addition, as many studies of HRIs and HAIs have shown, the embodied interaction capabilities of agents make them perceived as third parties (e.g., [87]). Thus, this can be an important dimension in designing an agent as a social mediator. In contrast, dimensions such as personality perceptions or embodiment of the agents, were not discussed in AI-MC [48]. Therefore, the concept of social mediator robot proposed in this study can be positioned as a subordinate concept of AI-MC as well as a reasonable extension of it.

2.1.3 Robot-Mediated Communication

In this section, the impact of the intervention of embodied artificial agents, such as robots, in people's communication is discussed based on the literature. In both HRI and HAI fields, numerous studies investigated the use of embodied agents in human communications. Vast majority of these studies is formed by telepresence robots and mediator robots, which are used in real-time human-human communication. For remote communication support, telepresence robots have been used as mediators of interpersonal communication, and the applicability was examined from multiple perspectives in the human support domain (e.g., healthcare [16, 79], working support [118, 55]).

On the other hand, social mediator robots for supporting local interpersonal communication were also proposed. These studies suggest that through interaction with mediator robots, humans may be encouraged to communicate with other people (e.g., [132, 144, 156]). For example, elderly people are motivated to interact with caregivers during their interaction with a Paro robot [144]. Furthermore, a social robot having a function to increase people's awareness to the effect of their behavior toward others, potentially leading to behavior change has been proposed [56]. If the robot detects the conversation between humans become aggressive, the robot responds by a gesture expressing its fear, and the communicators (human) may notice their own (aggressive) states.

However, there are very few studies that explore the use of AI agents for mediating human messaging in HRI and HAI. Although there are several commercially available products such as RoBoHoN [25] and Kokokuma [161], and a few studies that implement messaging capabilities in robots (e.g. [78, 142]), effective behavioral design guidelines for social mediator robots, especially robots that can intervene in human messaging as a third party, have not yet been discussed.

2.2 Contributions of the Present Research

Based on the above related works, the social mediator robot, which is the subject of this research, can be positioned in the CMC and HRI/HAI research fields as shown in Fig.2.1. This research contributes to the design of social mediator robots that will emerge in the future, by supplementing the limitations of conventional robots with messaging functions described in Chapter 1.

When people interact with a robot that mediates asynchronous communication, they might change the message content input to a mediator robot, taking into account how it delivers the message. In fact, in Chapter 5 and 6, the anxiety perceived by the message senders in a situation where they could or could not control how the mediator robot delivers their message to the other person was studied. The results showed that the participants reported less anxious when they know that the robot will deliver the message in a way that is appropriate for them. Thus, in the case of this research, there is always a person behind the robot, and the user communicates with that person while being influenced by the (mediator) robot's personality and interaction capabilities. Therefore, the contribution of this research is to provide experimental insights into this unique configuration of HRI, and is quite different from previous works that studied simple one-to-one human-robot interactions. Moreover, through a quantitative evaluation process, this research presents specific behavioral design guidelines for a mediator robot that are effective in two interpersonal communication situations: supporting elderly self-disclosure and intervening interpersonal conflicts.

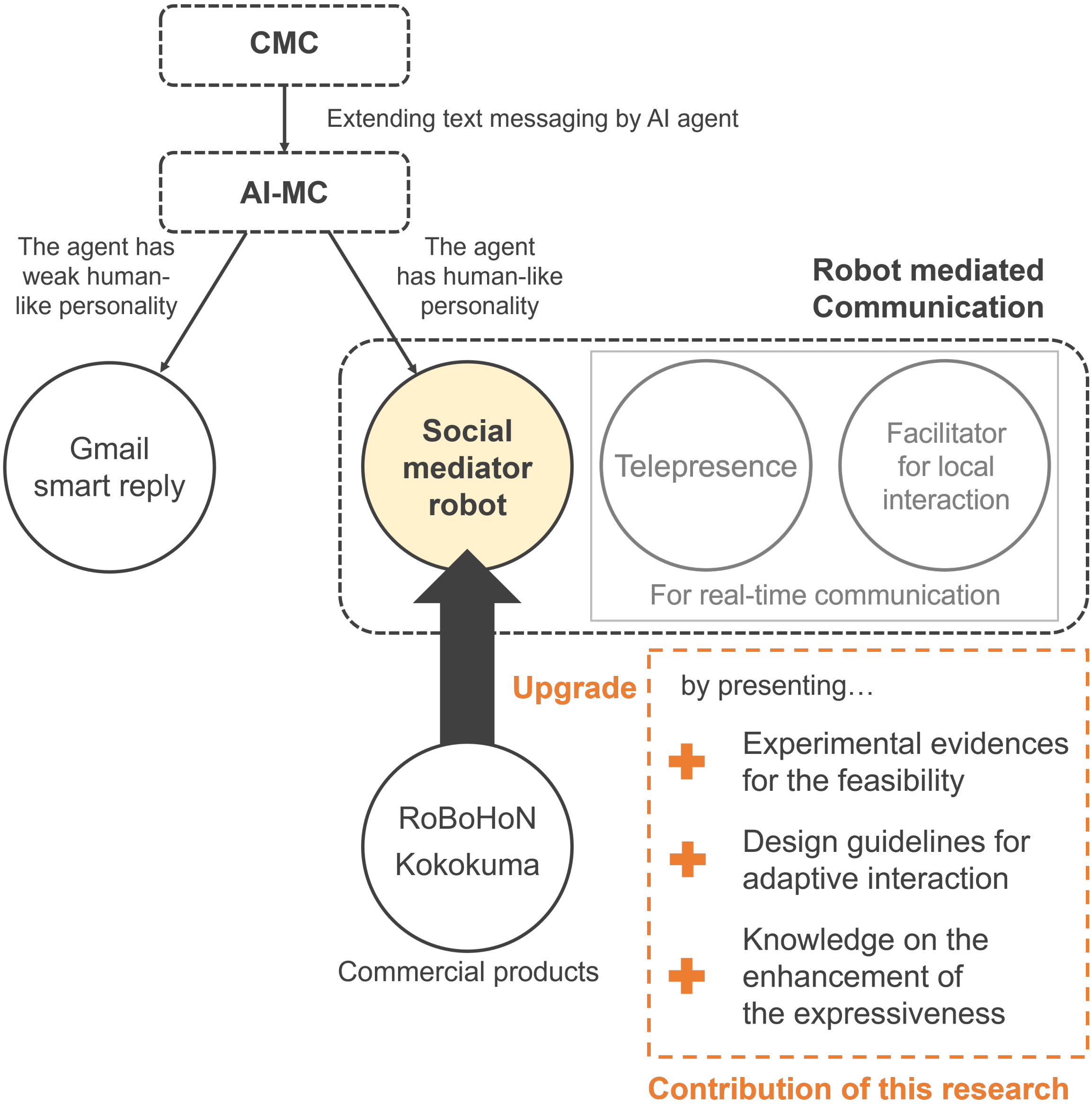

Fig. 2.1 Overall positioning of the social mediator robots discussed in this study in related fields and the contributions of the presented research

Chapter 3

Topics in Which Elderly People Feel Easier to Self-Disclose With Social Mediator Robot

In this chapter, the feasibility of social mediator robot for elderly people was explored, while addressing a research question “In what topics can the robot encourage elderly self-disclosure?” To this end, an HRI experiment in a laboratory setup was carried out. In addition, a relationship between participants’ social perception toward the mediator robots having different behaviors and the ease of self-disclosure was also analyzed. Before explaining the experimental procedures, this chapter presents a brief review of literature of self-disclosure of elderly people and HRI works discussing self-disclosure, followed by an introduction of the prototype robots which are used in this study. The contents of this chapter are based on the following publications:

- [112] Yohei Noguchi, Hiroko Kamide, and Fumihide Tanaka. Effects on Self-disclosure of Elderly Speakers by a Robot which Supports Remote Communication. The Transactions of Human Interface Society, 20(1):67–78 (in Japanese), 2018.

- [113] Yohei Noguchi, Hiroko Kamide, and Fumihide Tanaka. Personality Traits for Social Mediator Robot Encouraging Elderly Self-Disclosure on Loss Ex-periences. ACM Transactions on Human-Robot Interaction, 9(3), 2020. paper 17.

3.1 Related Works

3.1.1 Benefits of Self-disclosure

Self-disclosure has been of interest to philosophers, sociologists, and psychologists for a long time. In Encyclopedia of Social Psychology, self-disclosure was referred to as *"the process of revealing personal, intimate information about oneself to others"* [9]. Jourard pioneered a spectrum of researches concerning human self-disclosure [68] including its relationship between healthy personality. On the other hand, in developmental psychology, Erikson et al. defined the model of psychological conflict in elderly people as *integrity* vs. *despair* [35, 36]. Both are experienced when people reflect on their lives and think about what they have or have not accomplished. Self-disclosure becomes important in terms of the integrity. To self-disclose life experiences from the viewpoint of integrity refers to sharing memories with people of the same generation and teaching a moral to the younger generation; these act as therapeutic interventions for disclosers that mitigate their stress and enhance adaptation [47]. Furthermore, disclosing own troubles to other people can be a trigger for social support [163]. Social supports are classified into four aspects — emotional support, material support, informational support and appraisal support [60], and self-disclosure provides important information for these support.

Although there are many benefits in self-disclosure, troubles represented by loss experiences, i.e., *loss of physical/mental health*, *loss of economic base*, *loss of social networks*, and *loss of reasons to live*, are known as topics that are difficult for elderly people to disclose even to close persons (e.g., intimate friends or family members) [153]. On the other hand, interpersonal communication often become smooth if there is a third person mediator. Therefore, the difficulty of self-disclosure could be alleviated and elderly people might be encouraged to request social supports from others. Indeed, recent HRI research (see next sections) suggests that, if designed appropriately, robots can elicit both self-disclosure and human-human interaction.

3.1.2 Human-Robot Interaction and Self-disclosure

Relationships (e.g., trust, companionships, rapport) between disclosers and artificial entities have been regarded as a crucial factor of human self-disclosure [164, 177, 93]. Also, there have been proposed interaction strategies for building relationships between human and robot toward encouraging human self-disclosure (e.g., human-robot hugging [148], reciprocal self-disclosure [18], back-channeling [44]). These studies indicate that human self-disclosure can become deeper and broader as the relationship with the partner robot advances, based on the Social Penetration Theory [2]. On the other hand, it was proposed that robots were regarded as social entities to which people could self-disclose easily because robots did not share social statements with humans [165]. It was also reported that, compared with communication between humans, human self-disclosure of negative topics tended to be encouraged when humans communicated with a visually simple robot [81]. Overall, these studies suggest that personal robots can encourage the self-disclosure of negative topics, such as loss experiences, in the elderly people.

3.1.3 Robot-Mediated Communication

In the context of robot-mediated communication, although literature suggest the potential of mediator robots for elderly users (see section 2.1.3), design knowledge with respect to encouraging self-disclosure is still insufficient. Messaging functions in robots were studied (e.g. [78, 142]), but there has not been reported any effect on the self-disclosure of the elderly people, and effective design guidelines for social mediator robots have not been provided. Furthermore, individual differences become a particularly important element when using social robots in mental healthcare [129], thus mediator robots should be designed in accordance with individual user properties (e.g., personality traits, gender). It is considered that mediator robots should be able to adapt to each user depending on dialogue topics as well as the personality traits of the user.

3.2 Prototype Robots Used in this Study

3.2.1 General Features

Fig. 3.1 shows the appearance of two robots that were used in our studies explained in the following sections. The robots had been regarded as test beds (not final products) for our studies to explore important factors for designing mediator robots. Therefore, each of the robots was designed in a simple appearance to minimize the influence of robot appearance and prior knowledge on commercial robots. Based on opinions obtained at pilot workshops involving elderly persons who had been participating in our research projects as leaders for elderly participants, these robots were designed

Fig. 3.1 Robots used in our studies.

in a size to be used on a tabletop. In addition, following the knowledge reported in [90], two eyes were putted, to make the robots for home use.

Arduino microcontroller boards were used to control the servos. They were connected to laptops or small CPU boards (we tested on raspberry Pi and Latte Panda) with Python scripts running. The Python scripts provided speech, web server access, and high-level robot control, while the Arduino controlled the hardware that provided the physical expression. For the voice interaction function, we used the Google speech-to-text API for speech recognition and a text-to-speech API provided by NTT docomo for speech synthesis. We developed an https web server to manage messages that were posted and requested from the robots.

3.2.2 Type-A Robot

The left in Fig. 3.1 is Type-A robot (145 mm (H) × 130 mm (W) × 105 mm (D)). It is the first prototype which we developed based on the feedback obtained from a pilot study [109]. It has 4 DOFs (2 DOFs on the neck; head nod and swing, and 2 DOFs on the arms; left and right). The eyes are represented by two RGB LEDs. A microphone can be mounted on its right/left hand, and a camera is embedded on the face. This robot does not have a speaker module; thus, an external speaker is required. The Type-A robot was used in Chapter 3.

3.2.3 Type-B Robot

The right in Fig. 3.1 is Type-B robot (185 mm (H) × 155 mm (W) × 130 mm (D)). To conduct a study in Chapter 4 and 6, more DOFs in the head part were required than the case with the Type-A robot, and therefore we developed this Type-B robot. It has 6 DOFs (3 DOFs on the neck; head nod, tilt, and swing, 2 DOFs on the arms; left and right, and 1 DOF for body rotation). The eyes are represented by micro OLED displays (SparkFun LCD-13003) and controlled by Arduino Nano using the SPI communication method. A camera with a microphone module is built into the head, and a small speaker module is mounted on the chest.

3.3 Hypothesis

As reported in the area of computer-mediated communication (CMC), self-disclosure of human tends to be encouraged [66, 100], particularly under a condition in which the effect of nonverbal cues is small [166]. A similar effect could be expected with mediator robots because the effect of nonverbal cues of humans exchanged via the robots can be controlled. Also, expressive behaviors of social robots encourage self-disclosure [93, 85], and social behaviors such as greetings, nodding, blinks, etc. are more acceptable for elderly people [52]. When topics are not so intimate for individuals (e.g., everyday experiences or their own positive memories), it is easy for them to disclose regardless of communication media. However, mediator robots equipped with social expressive behaviors could affect elderly self-disclosure even on intimate topics such as loss experiences. Therefore, we constructed the following hypothesis.

H1. *In topics concerning loss experience, elderly self-disclosure is encouraged when a mediator robot having socially expressive behaviors is used.*

3.4 Method

3.4.1 Participants

In conducting an experiment, a communication scenario between an elderly "parent" (N = 21) and his/her "daughter" was prepared. The reasons for using this scenario were (1) as described initially in Chapter 1, we ultimately aimed for tackling the issue of social isolation in elderly people who lived separately from their family members, and (2) a study suggested that daughters tended to communicate with their parents more frequently than sons [135]. With this in mind, we selected elderly participants who actually had adult daughters. The average age of the parent participants was 72.0 (*SD* = 5.12; 9 men, 12 women). A female college student who often communicated with her parents took the role of the daughter, being a recipient of self-disclosure. The details of the scenario used in the experiment are described in Section 3.4.5. This study was conducted with the approval of the research ethics committee of the faculty of engineering, information, and systems of the University of Tsukuba (2015R109-3), and consent was obtained from each participant based on an informed concept.

3.4.2 Experimental Design

The medium of communication used by the participants was manipulated in the experiment. There were three conditions: (1) phone condition: no robot but phones were used, (2) expressive robot condition: a mediator robot with social expressions was used, and (3) non-expressive robot condition: a mediator robot with no social expression was used.

In using the robot in (2) and (3), messages were converted from voice to text and sent to the daughter's smartphone remotely (the robot was used by the elderly's side only). The experiment was designed to be accompanied by vocalization under all conditions, to avoid creating a gap of cognitive load on task. Every participant joined all the three conditions in a random order. For measuring the ease of self-disclosure, only the data obtained from the first condition to each participant were used (between-participants factor) to control the degree of their experience on the robot. On the other hand, for measuring social attributes toward the robot, data were collected and analyzed for a within-participant factor.

3.4.3 Robots Used in the Experiment

Type-A robot (left in Fig. 3.1) was used as a base platform. Then, we programmed in two different ways, having the following two robots used in the experiment.

Expressive Robot

This robot responded to two types of voice commands, "send a message" and "check a message." It was also equipped with verbal and non-verbal expressions. When participants called "send a message," the robot nodded and then said "What should I tell to her?" Recording began with a microphone mounted on the right arm of the robot. The recording continued for 20 seconds, afterwards, the robot asked for confirmation and sent it to the daughter. Alternatively, when participants called "check a message," the robot nodded and then said "I will check messages, please wait a moment." Then, if there was any message, the robot read it out. If there was no message, the robot just said "I do not have any new message."

Non-expressive Robot

In contrast, the robot for the non-expressive condition used beeps and LED colors. The robot responded to the same two voice commands as the case with the expressive robot. When the "send a message" command was called, the robot sounded a 587 Hz beep and began recording the user's voice for 20 seconds. Then, a 494 Hz beep sounded to notify the end of the recording, and the voice message was sent to the daughter's smartphone. When the "check a message" command was called, the robot read out the message if there was any new message arrived. If not, the robot beeped at 493 Hz twice.

3.4.4 Measurements

Ease of Self-disclosure

The self-disclosure scale created by Suganuma [153] was used to evaluate the ease of self-disclosure under each condition. This scale comprises 16 items and three factors: *everyday experience* (4 items), *integrated life experience* (7 items), and *loss experience* (5 items). By using a questionnaire, the ease of self-disclosure can be measured on a scale of "1: quite hard to talk" to "6: quite easy to talk."

Social Attribute of Robots

A robotic social attribute scale (RoSAS) [20] was used. This scale has six items on each of the three factors: *warmth*, *competence*, and *discomfort*, and it was reported that robots with human-like appearance scored higher warmth and competence than robots with machine-like or human-machine blended appearance. In our study, the scale was used for a manipulation check to confirm that warmth and competence judgements on a mediator robot with social expression were greater than a robot with mechanical expression. This is because the social expression of robots was known to enhance people's perception of robots as more human-like [39].

Impression on the Recipient

Because participants' subjective impressions to the recipient (daughter) were considered to affect the ease of self-disclosure, we inquired impressions on the daughter person of the participants, based on a scale of "1: She was hard to speak with" to "5: She was very easy to speak with." The data were used as a covariance in later analyses (Section 3.5.2).

3.4.5 Experimental Procedure

Each elderly participant was given a general explanation about this study and asked for his/her consent at beginning. In consequence, all participants consented to all terms including the disclosure of their personal information. Then, the elderly participant had a short meeting with a daughter person, by introducing each other. After that, both of them left out and re-entered into two separate rooms. Fig. 3.2 shows one of the rooms for elderly participants. At this moment, the elderly participant was provided with a scenario for the experiment, in which he/she was supposed to speak of his/her own episode based on three subjects: recent enjoyment, an unforgettable experience, and health concerns. These were selected from a questionnaire used to measure the ease of self-disclosure described in Section 3.4.4. The elderly participant was given a paper and instructed to write their three episodes in the paper in advance so that he/she would be able to explain each episode in 20 seconds.

The daughter person was instructed and trained in advance such that she was supposed to receive a call/message from her parent who lived separately from her. In responding to each call/message, she was allowed to use only three kinds of replies: for recent enjoyment topics, "That's funny! Good for you!"; for unforgettable experience topics, "Did that really happen? It's unforgettable."; and for health concerns topics, "That must be concerning for you. We need to be careful about health."

In the phone condition, the elderly participant was given a smartphone and instructed to call when he/she was ready. Upon connecting with the daughter person, and after initial greetings, the participants discussed the three topics.

In the expressive robot and non-expressive robot conditions, there was a training phase at first in which each participant could get used to robot-mediated communi-

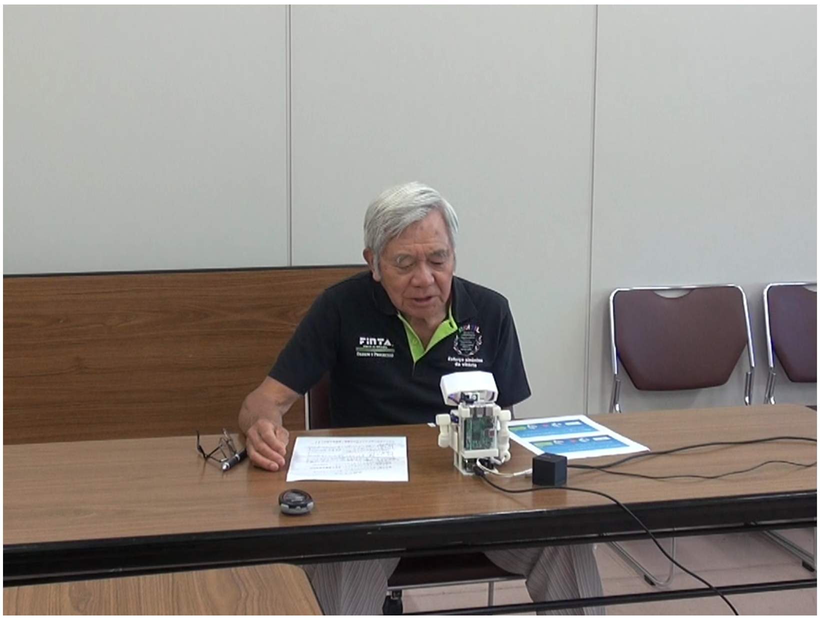

Fig. 3.2 A participant speaking out to a mediator robot.

cation, by being instructed how to use the robot, send messages, and how replies from the daughter person came. After the training phase, the participant was guided into the communication task with the daughter person.

During the experiment, the experimenter had been waiting outside the room. On average, it took about 3 minutes per session in the phone condition and about 10 minutes per session in the robot conditions including the transaction time. After the communication task ended, the participant was asked to answer to the questionnaire described in the previous section.

3.5 Results

3.5.1 Manipulation Check

For a warmth factor in RoSAS, the expressive robot was rated significantly warmer ($M = 4.32$, $SD = .90$) than the non-expressive robot ($M = 3.67$, $SD = 1.06$; $t(20) = 3.02$, $p = .007$, $d = .66$). For a competence factor, the expressive robot was rated significantly more competent ($M = 4.44$, $SD = 1.04$) than the non-expressive robot ($M = 3.76$, $SD = 1.00$; $t(20) = 3.05$, $p = .006$, $d = .67$). From these results, the robot with social expression was perceived as more expressive. Therefore, we concluded that the behaviors of the robots were well manipulated.

3.5.2 Statistical Analysis

Firstly, we examined if participants' impression on the daughter person (ease of talking with) had affected their ease of self-disclosure. To this end, we performed a parameter estimation by a linear regression analysis with the ease of self-disclosure as a dependent variable, the communication medium as an independent variable, and the impression on the daughter person as a covariance. Then, in topics concerning *everyday experience*, the effect of the covariance was found to be significant (B = .63, $F(1,17)$ = 15.1, p = .001, ${\eta_p}^2$ = .47). In contrast, no significant coefficient of the covariance was found in topics concerning *integrated life experience* (B = .24, $F(1,17)$ = 1.74, p = .20, ${\eta_p}^2$ = .093) nor in topics concerning *loss experience* (B = .28, $F(1,17)$ = 2.28, p = .15, ${\eta_p}^2$ = .12). Furthermore, a two-way ANOVA showed no significant interaction between the communication medium and the impression on the daughter person in topics concerning *everyday experience* ($F(2,15)$ = 1.51, p = .25, ${\eta_p}^2$ = .17). Thus, it was concluded that the impression of the daughter person had affected the ease of self-disclosure only in topics concerning *everyday experience*, which was independent of the communication medium.

Therefore, in examining the effect of a communication medium factor on the ease of self-disclosure, we decided to use a one-way ANCOVA with the impression on the daughter person as a covariance in topics concerning *everyday experience*, and use a one-way ANOVA in other topics.

3.5.3 Ease of Self-disclosure

Fig. 3.3 shows the average scores of the ease of self-disclosure of each communication medium in three kinds of topics.

As explained in the previous section, for topics concerning *everyday experience*, a one-way ANCOVA was performed. The results showed a marginal effect of the medium factor ($F(2,17)$ = 2.96, p = .079, ${\eta_p}^2$ = .26). Post hoc comparisons using t-tests with Bonferroni correction showed that there was a marginally significant difference between the expressive robot condition (M = 5.11, SD = .86) and the non-expressive robot condition (M = 3.82, SD = .66; $t(17)$ = 2.33, p = .097, d = 1.31). No significant difference was found between the phone condition (M = 4.29, SD = .64) and other two robot conditions.

Then, for topics concerning *integrated life experience* and *loss experience*, a one-way ANOVA was performed. In topics concerning *integrated life experience*, there was a marginally significant effect of the medium factor ($F(2,18)$ = 3.40, p = .056, ${\eta_p}^2$ = .27).

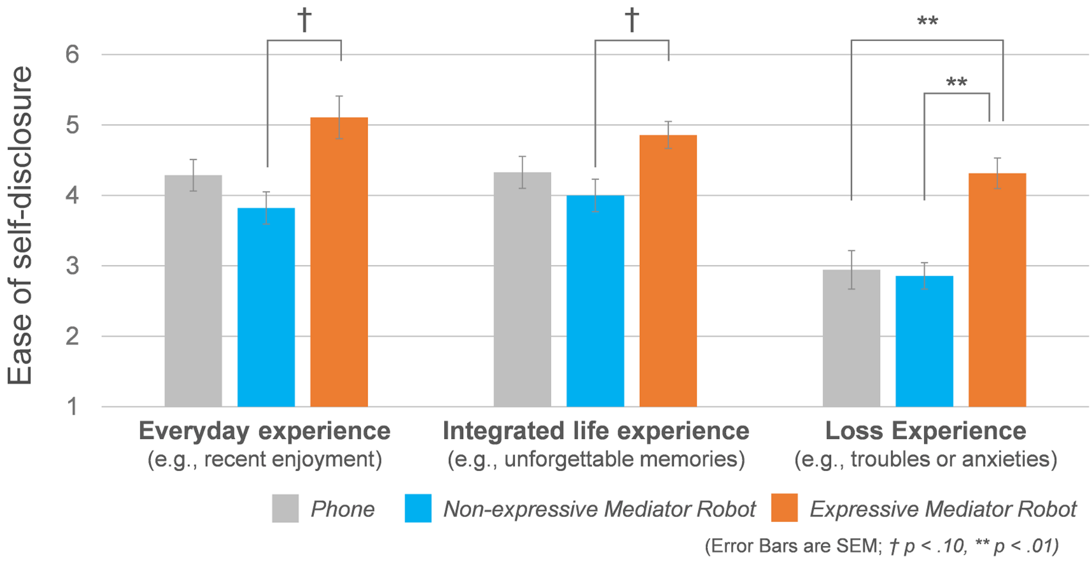

Fig. 3.3 Ease of self-disclosure through different communication media: the results show that elderly participants judged the mediator robot with social expressions (expressive robot condition) as the easiest medium for self-disclosing their loss experiences.

Post hoc comparisons showed that the mean score for the expressive robot condition (M = 4.86, SD = .55) was marginally larger than the case with the non-expressive robot condition (M = 4.00, SD = .66; $t(18)$ = 2.58, p = .056, d = 1.41). No significant difference was found between the phone condition (M = 4.33, SD = .65) and other two robot conditions.

Finally, in topics concerning *loss experience*, there was a significant effect of the medium factor ($F(2, 18) = 10.9$, p = .001, $\eta_p{}^2$ = .55). Post hoc comparisons showed that the mean score for the expressive robot condition (M = 4.31, SD = .62) was significantly larger than the cases with the phone condition (M = 2.94, SD = .78; $t(18)$ = 3.92, p = .003, d = 1.95) and the non-expressive robot condition (M = 2.86, SD = .54; $t(18)$ = 4.17, p = .002, d = 2.51).

3.6 Discussions and Limitations

The results suggest that the mediator robot with social expressions was regarded as more expressive and, when elderly participants self-disclosed through such a medium, the ease of self-disclosure increased, particularly in talking their loss experiences. Therefore, the hypothesis **H1** was considered to be supported.

In telecommunication using the mediator robot, the effect of nonverbal cues transmitted in real-time was much smaller than that of phone or video calls. It was reported in computer-mediated communication (CMC) researches that communication media with weak nonverbal cues (e.g., e-mails) positively affect human self-disclosure due to small cognitive loads and selective self-presentation [166]. On the other hand, no significant difference was observed between the non-expressive robot condition and the phone condition. This might have been because the robot required the speech of the users, which was different from previous CMC devices using keyboard inputs. Users tend to hesitate and feel embarrassed if the response of a robot is not good. Mediator robots should be designed so that their social expressions in making responses can be perceived as expressive.

It is noteworthy that the perception of a mediator robot as expressive could affect elderly self-disclosure much stronger than its functional specification such as the number of nonverbal cues or asynchronicity. The results also show that both the verbal and nonverbal expressions, implemented in the expressive robot condition, are examples of behaviors that strengthen the human perception of the mediator robot as a social entity.

However, we also have to be aware of the limitations of this study. First, the sample size ($N = 7$ per condition) was small. Next, there were multiple factors between the phone condition and the robot conditions, and the study did not completely control them. For example, in the phone condition, participants spoke in real time with the confederate although the conversation was controlled to some extent by a predefined script and response patterns, whereas, in the robot conditions, the conversation was made strictly step by step.

In this study, we explored dialogue topics in which social mediator robots could well encourage the self-disclosure of elderly people. The results suggest that in topics concerning *loss experience*, introducing social mediator robots can be particularly effective, compared to direct conversations over phones. By using the social mediator robots, the elderly's hesitation or psychological resistance in self-disclosure could be alleviated. A possible reason would be due to the avoidance of receiving negative feedback directly from recipients. Also, as [165] suggested, since robots do not share social statements with humans, disclosers can self-disclose with little concern for receiving negative feedback from the mediator robots. Therefore, although it is necessary for mediator robots to be regarded as social others, elderly self-disclosure may be suppressed if the robots are too much human-like.

Chapter 4

Personality Traits for Social Mediator Robots to Encourage Elderly Self-disclosure on Loss Experiences

In this chapter, an online survey research exploring a research question, "How the robot's character should be personalized to the elderly user?" is described. A toal of 720 elderly people participated in the online survey research. Video stimuli, each of which contained a type of mediator robot having one of different personality traits, were used in the survey. The contents of this chapter are based on the following publications:

- [113] Yohei Noguchi, Hiroko Kamide, and Fumihide Tanaka. Personality Traits for Social Mediator Robot Encouraging Elderly Self-Disclosure on Loss Ex-periences. ACM Transactions on Human-Robot Interaction, 9(3), 2020. paper 17.

4.1 Hypotheses

In the HRI research field, it is well-known that matching robot personality brings a positive influence on the humans' task performance [3, 86, 99, 158, 7]. The extroversion dimension of the Big Five personality model [65] was often employed, and the theory of similarity-attraction, i.e., a person was attracted more to others who were matched in personality than to those who were mismatched, was discussed [104, 103]. It was also reported that mutual self-disclosure increased among similar extroverted dyads [29]; therefore, a match in extroversion between a robot and the user could positively affect the depth of the user's self-disclosure.

On the other hand, the amount of self-disclosure tends to become smaller from elderly people with lower self-esteem [153]. Self-esteem concerns the adaptation levels of humans [73], and is known to be negatively correlated with neuroticism [5] that is another dimension of the Big Five personality model. Therefore, in case having high neuroticism (low self-esteem), even if the personality of a robot is matched to the one of the user, the user's self-disclosure to the robot could be suppressed. As a consequence, we have the following hypotheses:

H2a. *Matching personality traits of a mediator robot to the elderly user with low neuroticism increases his/her depth of self-disclosure (similarity-attraction).*

H2b. *Matching personality traits of a mediator robot to the elderly user with high neuroticism decreases his/her depth of self-disclosure (similarity-repulsion).*

To distinguish *similarity-attraction* and *similarity-repulsion* statistically, we need to consider at least one more personality trait (variable) other than neuroticism. Therefore, in this study, we will observe not only main effects concerning neuroticism but also interactions involving extroversion, and then discuss both the *similarity-attraction* and *similarity-repulsion*, whose definitions are given as follows:

Similarity-attraction: A depth of self-disclosure of an elderly user **increases** if personality traits (neuroticism and extroversion) of a mediator robot match the ones of the elderly user, compared with the cases with a single-match (matched in either neuroticism or extroversion).

Similarity-repulsion: A depth of self-disclosure of an elderly user **decreases** if personality traits (neuroticism and extroversion) of a mediator robot match the ones of the elderly user, compared with the cases with a single-match (matched in either neuroticism or extroversion).

4.2 Method

4.2.1 Participants

Participants for this study were recruited through the panel of MACROMILL, Inc. which is a leading market research company in Japan. Initially, we obtained 720 participants over 65 years (all Japanese, M = 69.8 years, SD = 4.11, 50 % female and 50 % male). However, we excluded data obtained from 131 participants who were not confident in understanding all the survey procedure (measured by a question item), and therefore data from 589 participants were used in analyses in the end. The target profiles of participants in the recruitment were: (1) persons who were communicating with their own children and intimate friends at least once in three years by phone or face to face; (2) persons who were living alone or with their spouses only; (3) persons who had own troubles regarding either of loss experience topics (health, financial, isolation, and reasons to live[1]) that had never been disclosed to their family members or friends. To exclude participants who did not meet those requirements, a screening process was carried out before proceeding to the main survey. The fieldwork period was from December 17th to December 19th in 2018 and was conducted by MACROMILL, Inc.

4.2.2 Video Stimuli

Prerecorded video clips simulating human-robot conversations taken from the first-person perspective were used. There were four video clips each of which contained one of four robots having different personality traits (high/low extroversion and high/low neuroticism). The robots were based on a Type-B robot (right in Fig. 3.1). The time length of each video clip was about 40 seconds. The dialogues taken in the video clips were consisted of two parts: in the first half, the robot behaved to express its extroversion, whereas neuroticism was expressed through its behaviors in the second half. Examples of the simulated conversations are shown in Table 4.1. Although the voices of the robots were recorded, the utterances of disclosers were presented by subtitles only (no voice). These video clips are available on the links in the footnote[2].

Studies in psychology showed that extroverts tend to have a higher speech rate and produce more utterances and also have higher gesture rates than introverts [41, 88]. These traits have also been tested into artificial agents [3, 86, 99, 158, 7]. Following these knowledge, we implemented extroverted and introverted behaviors with

[1] In the questionnaire, we asked: "Do you have experiences regarding; troubles concerning your own health and illness (health); troubles concerning living income and savings (finance); troubles concerning people whom you can depend on disappearing and you become alone (isolation); you cannot feel reasons to live (reasons to live)?"

[2] HE+HN robot: https://youtu.be/z-f6Gk4-XbY; HE+LN robot: https://youtu.be/IYP9q9kN-z4; LE+HN robot: https://youtu.be/2EnGWRNYE-0; LE+LN robot: https://youtu.be/E-4Pasn4EYE.

Table 4.1 Examples of simulated human-robot conversations. In both of these examples, the first half concerns the extroversion trait (HE/LE) of the robot, and the second half concerns the neuroticism trait (HN/LN) of the robot.

(a) HE+HN Robot

Speaker	Utterance
Discloser:	"I want to send a message."
Robot:	That's what I have been waiting for.
	You can send a message to that person! Please say anything!
Discloser:	"Recently, I'm in trouble with **, and I'd like you to listen to me..."
Robot:	Ok, I see... That must have been really hard for you.
	I will pass your message responsibly.
	But I know you have such a problem, I'm in panic right now.
	I'm feeling awkward.

(b) LE+LN Robot

Speaker	Utterance
Discloser:	"I want to send a message."
Robot:	OK. You can send a message to that person. So, what is your message?
Discloser:	"Recently, I'm in trouble with **, and I'd like you to listen to me..."
Robot:	Ok, I see... That must have been really hard for you.
	I will pass your message responsibly.
	It is important to calm down at such a moment. I will handle myself well.

verbal (voice pitch, speed, and phrases) and nonverbal (the speed/frequency of head nodding, tilt, gaze, and arm movements) expressions. For vocal expressions, we used a text-to-speech API provided by NTT docomo. The high extroversion (HE) robot spoke more phrases than the low extroversion (LE) robot, expressing joy with +10 % pitch, +10 % speed, together with configuring an emotion parameter provided by the API with "happiness." In contrast, the LE robot spoke fewer phrases than the HE robot, in neutral pitch and speed, configuring the emotion parameter with "neutral." The HE robot held eye contact, while the LE robot was programmed with a gaze-aversion based on a model reported in [6], looking to its top, left, right, and bottom once in every 7 seconds, by a ratio of 1:2:2:5. The HE robot also showed head and arm movements two times faster and more frequently than the LE robot.

It was reported that people with high neuroticism are looked as being forced, awkward, or strained by their interlocutors during interactions [29, 40]. We then implemented the high neuroticism (HN) robot such that it showed signs of tension or anxiety during interactions. The HN robot verbally expressed insecurity and sensitivity by +10 % pitch, +10 % speed[3], together with configuring the emotion parameter with “sadness.” In addition, to show awkwardness, the robot trembled several times with its head and arm. On the other hand, the low neuroticism (LN) robot verbally expressed emotional stability toward the user’s self-disclosure, in a stable speed and pitch.

4.2.3 Measurements

Perception of Robot Personality Traits

For the purpose of a manipulation check, we measured how participants perceived different personality traits of the robots in the video stimuli explained in the previous section. The ten items personality inventory (TIPI-J [120]) was used to evaluate the extroversion and neuroticism of the robots. Question items for evaluating the robot’s extroversion were: “This robot is extraverted and/or enthusiastic.” and “(-) This robot is reserved and/or quiet.”; and question items for evaluating the robot’s neuroticism were: “This robot is anxious and/or easily upset.” and “(-) This robot is calm and/or emotionally stable.” A seven-point scale of “1: strongly disagree” to “7: strongly agree” was used in answering to these question items.

Depth of Self-disclosure to the Robot

To measure the depth of the participants’ self-disclosure to the robot, we asked them to evaluate how much they wanted to talk to the robot. A seven-point scale of “1: I do not want to talk at all.” to “7: I want to talk in full details” was used for this measurement.

Personality Traits of Participants

A Big Five scale [102] was used to evaluate the extroversion and neuroticism of each participant, which was represented by five items; extroversion: (-) quiet, sociable, talkative, extrovert, and cheerful; neuroticism: uneasy, anxious, discouraged, nervous, and depressive. A seven-point scale of “1: strongly disagree” to “7: strongly agree” was used in answering to the question items.

[3]In case of the HE+HN robot, the pitch and speed were both increased a total of 20 % from their baselines.

Self-esteem in Participants

Rosenberg's self-esteem scale [133] was used to check correlations between participants' self-esteem and neuroticism. A four-point scale consisted of "1: strongly disagree," "2: disagree," "3: agree," and "4: strongly agree" was used for this survey.

4.2.4 Procedure

At beginning, an experimenter explained the basic concept of mediator robots and the purpose of this study to each participant. Then, the participant was instructed to watch four video clips explained in Section 4.2.2 in a random order assigned. After that, he/she was asked to answer to questions about robot personality (Section 4.2.3) and self-disclosure (Section 4.2.3), followed by another set of questions as to the participant's personality (Section 4.2.3) and self-esteem (Section 4.2.3). Lastly, as explained in Section 4.2.1, the participant's comprehension about this survey was checked by using the two questions: "I could not understand some video contents." and "I could not understand how the mediator robot works." The participant could assess his/her comprehension based on a seven-point scale of "1: strongly no" to "7: strongly yes." Results data obtained from the participants who marked a 5-7 on either/both of the questions were excluded from analyses.

4.2.5 Experimental Design and Statistical Analysis

Participants were divided into 2 × 2 groups based on high/low extroversion and high/low neuroticism by using median values[4] obtained from the Big Five scale (Section 4.2.3) with a boundary value of 4.00. The structure of the participants is summarized in Table 4.2.

On all topics and personality traits, a 2 × 2 × 2 split-plot factorial ANOVA was performed on the depth of self-disclosure to each robot, with the factors of the gender of participants (between-participants factor), extroversion traits of the robot

[4]The mean extroversion value was 4.95 (SD = .60) in the HE (high extroversion) group, and 3.22 (SD = .66) in the LE (low extroversion) group. There was a significant difference between them ($t(587) = 32.9$, $p < .001$, $d = 2.72$). The mean neuroticism value was 4.84 (SD = .56) in the HN (high neuroticism) group, and 3.28 (SD = .62) in the LN (low neuroticism) group. There was a significant difference between them ($t(586.0) = 32.3$, $p < .001$, $d = 2.66$; the assumption of homoscedasticity was violated.)

Table 4.2 The participants structure divided by personality traits and topics chosen by them at the time of their recruitment. HE: high extroversion. LN: low neuroticism.

	Personality traits			
Topics	HE+HN	HE+LN	LE+HN	LE+LN
Health	33 (18 males)	56 (22 males)	24 (15 males)	38 (20 males)
Finance	19 (7 males)	45 (22 males)	38 (13 males)	37 (23 males)
Isolation	27 (14 males)	41 (18 males)	48 (26 males)	35 (20 males)
Reasons to live	32 (11 males)	29 (14 males)	53 (31 males)	34 (18 males)
Total (N = 589)	111 (50 males)	171 (76 males)	163 (85 males)	144 (81 males)

(within-participants factor), and neuroticism traits of the robot (within-participants factor)[5].

4.3 Results

4.3.1 Manipulation Check: Perception of Robot Personality Traits

Before using repeated measure one-way ANOVA, we performed Mauchly's sphericity test. It showed that the violation of sphericity occurred on each personality trait (extroversion: $\chi^2(2) = 56.0$, $p < .001$; neuroticism: $\chi^2(2) = 213.8$, $p < .001$). Therefore, we corrected the degrees of freedom by using Greenhouse-Geisser estimates of sphericity (extroversion: $\epsilon = 0.94$; neuroticism: $\epsilon = 0.80$). Then, repeated measure one-way ANOVA was performed. The results showed significant differences of participants' perception of the robot's extroversion ($F(2.83, 1665) = 104.6$, $p < .001$, ${\eta_p}^2 = .15$) and neuroticism ($F(2.40, 1411) = 254.7$, $p < .001$, ${\eta_p}^2 = .30$), and t-tests with Bonferroni correction showed that the personality traits of the robots were manipulated successfully: the robots with high extroversion were perceived higher in extroversion traits than the robots with low extroversion ($p < .001$)[6], and the robots with high neuroticism were perceived higher in neuroticism traits than the robots with low neuroticism ($p < .001$)[7]

[5] In this study, we first divided participants into four groups based on their personality traits (extraversion and neuroticism), and then performed ANOVA in each of those groups. Therefore, our ANOVA did not include the factors of participants' personality traits.

[6] HE+HN $M = 3.98$ ($SD = .88$); HE+LN $M = 4.13$ ($SD = .88$); LE+HN $M = 3.49$ ($SD = .80$); LE+LN $M = 3.56$ ($SD = .76$)

[7] HE+HN $M = 4.17$ ($SD = 1.11$); LE+HN $M = 4.15$ ($SD = 1.13$); HE+LN $M = 3.16$ ($SD = .89$); LE+LN $M = 3.08$ ($SD = .89$)

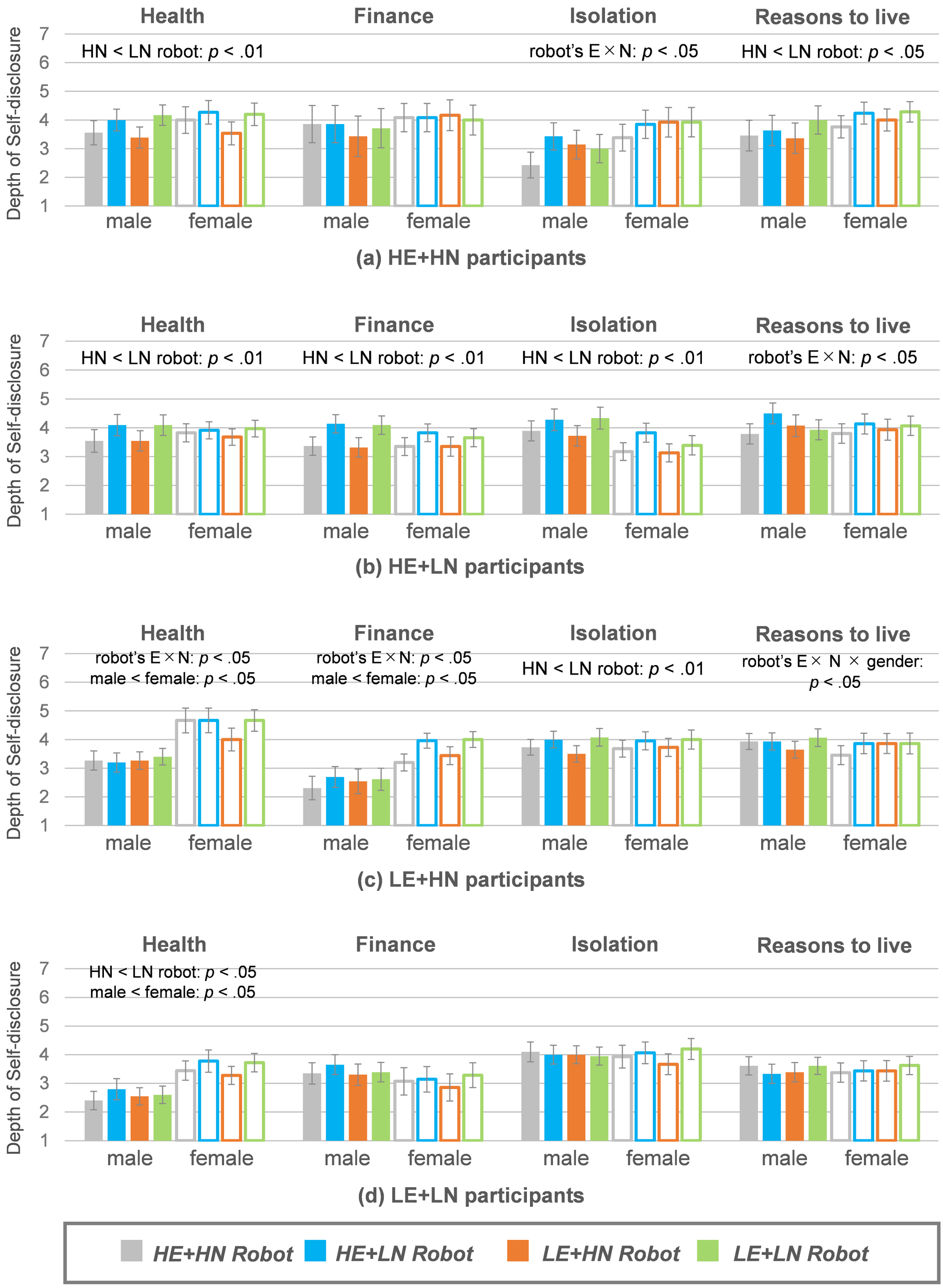

Fig. 4.1 The depth of self-disclosure measured from participants against four types of robots having different personality traits. "HE+HN Robot" denotes the robot having high extroversion trait (HE) and high neuroticism trait (HN), whereas "LE+LN participants" denotes the participants having low extroversion trait (LE) and low neuroticism trait (LN). The results are divided by four kinds of topics chosen initially by participants at the time of their recruitment: *health*, *finance*, *isolation*, and *reasons to live*.

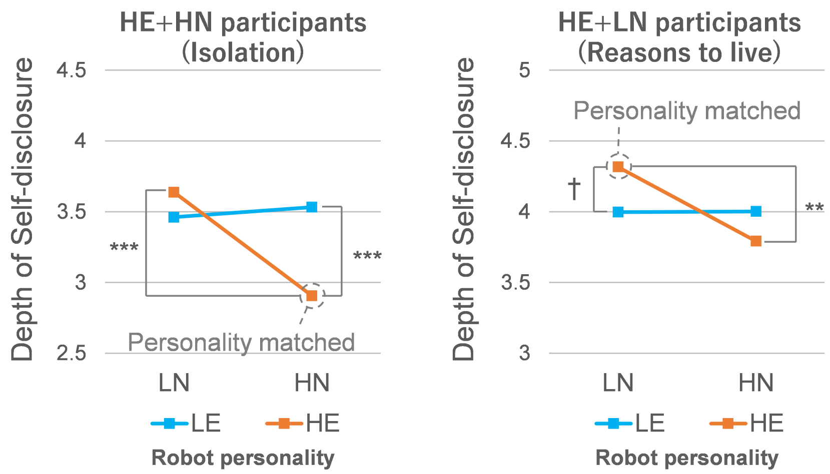

Fig. 4.2 Matching robot personality to participants having high extroversion (HE): similarity-attraction was observed in the participants having low neuroticism (HE+LN participants), while similarity-repulsion was observed in the participants having high neuroticism (HE+HN participants).

4.3.2 HE+HN Participants

The marginal means of the depth of self-disclosure obtained from the HE+HN participants are shown in Fig. 4.1a. There was a significant main effect of the neuroticism trait of the robots in two kinds of topics: the depth of self-disclosure to LN (low neuroticism) robots was larger than the case with HN (high neuroticism) robots in topics concerning *health* ($F(1,31) = 7.65$, $p = .009$, ${\eta_p}^2 = .20$) and *reasons to live* ($F(1,30) = 5.44$, $p = .027$, ${\eta_p}^2 = .15$).

There was also a significant interaction between two personality traits (extroversion and neuroticism) of the robots in topics concerning *isolation* ($F(1,25) = 4.88$, $p = .037$, ${\eta_p}^2 = .16$). Then, post hoc comparisons using t-tests showed significant differences in the average depth of self-disclosure between the robot having high extroversion and high neuroticism (HE+HN robot: matched to the HE+HN participants, $M^* = 2.91$, $SD^* = 1.68$[8]) and LE+HN robot ($M^* = 3.53$, $SD^* = 1.86$; $t(60) = 3.88$, $p < .001$, $d = .35$) as well as HE+LN robot ($M^* = 3.64$, $SD^* = 1.78$; $t(60) = 3.65$, $p < .001$, $d = .42$), which is illustrated in Fig. 4.2 (left).

[8] M^* denotes a marginal mean and SD^* denotes a standard deviation. We used SPSS Version 24.0 to calculate statistics.

4.3.3 HE+LN Participants

The marginal means of the depth of self-disclosure obtained from the HE+LN participants are shown in Fig. 4.1 (b). There was a significant main effect of the neuroticism trait of the robots in three kinds of topics: the depth of self-disclosure to LN (low neuroticism) robots was larger than the case with HN (high neuroticism) robots in topics concerning *health* ($F(1,54) = 8.80$, $p = .004$, ${\eta_p}^2 = .14$), *finance* ($F(1,43) = 19.6$, $p < .001$, ${\eta_p}^2 = .31$), and *isolation* ($F(1,39) = 8.11$, $p = .007$, ${\eta_p}^2 = .17$).

There was also a significant interaction between two personality traits (extroversion and neuroticism) of the robots in topics concerning *reasons to live* ($F(1,27) = 5.73$, $p = .024$, ${\eta_p}^2 = .18$). Then, post hoc comparisons showed a significant difference in the average depth of self-disclosure between the robot having high extroversion and low neuroticism (HE+LN robot: matched to the HE+LN participants, $M^* = 4.32$, $SD^* = 1.35$) and HE+HN robot ($M^* = 3.79$, $SD^* = 1.32$; $t(54) = 3.14$, $p = .003$, $d = .39$), and a marginally significant difference between the HE+LN robot and LE+LN robot ($M^* = 4.00$, $SD^* = 1.30$; $t(54) = 1.97$, $p = .054$, $d = .24$), which is illustrated in Fig. 4.2 (right).

4.3.4 LE+HN Participants

The marginal means of the depth of self-disclosure obtained from the LE+HN participants are shown in Fig. 4.1 (c). There was a significant main effect of the neuroticism trait of the robots: the depth of self-disclosure to LN (low neuroticism) robots was larger than the case with HN (high neuroticism) robots in topics concerning *isolation* ($F(1,46) = 11.0$, $p = .002$, ${\eta_p}^2 = .19$). There was a significant main effect of the gender of the participants in two kinds of topics: the depth of self-disclosure in female participants was larger than that in male participants in topics concerning *health* ($F(1,22) = 6.82$, $p = .016$, ${\eta_p}^2 = .24$) and *finance* ($F(1,36) = 6.02$, $p = .019$, ${\eta_p}^2 = .14$).

There was a significant interaction between two personality traits (extroversion and neuroticism) of the robots in two kinds of topics concerning *health* ($F(1,22) = 5.67$, $p = .026$, ${\eta_p}^2 = .21$) and *finance* ($F(1,36) = 4.23$, $p = .047$, ${\eta_p}^2 = .11$). Then, we performed post hoc comparisons. In the *health* topics, significant differences were found in the average depth of self-disclosure between the robot having low extroversion and high neuroticism (LE+HN robot: matched to the LE+HN participants, $M^* = 3.63$, $SD^* = 1.22$) and HE+HN robot ($M^* = 3.97$, $SD^* = 1.34$; $t(44) = 2.04$, $p = .047$, $d = .26$) as well as LE+LN robot ($M^* = 4.03$, $SD^* = 1.16$;

$t(44) = 2.27$, $p = .028$, $d = .34$), which is illustrated in Fig. 4.3 (Health). Next, in the *finance* topics, two significant differences and a marginally significant difference in the average depth of self-disclosure were found as illustrated in Fig. 4.3 (Finance): a significant difference between the robot having low extroversion and high neuroticism (LE+HN robot: matched to the LE+HN participants, $M^* = 2.99$, $SD^* = 1.64$) and LE+LN robot ($M^* = 3.31$, $SD^* = 1.46$; $t(72) = 2.22$, $p = .030$, $d = .21$), a significant difference between HE+HN robot ($M^* = 2.75$, $SD^* = 1.56$) and HE+LN robot ($M^* = 3.33$, $SD^* = 1.38$; $t(72) = 3.99$, $p < .001$, $d = .39$), and a marginally significant difference between the LE+HN robot and the HE+HN robot ($t(72) = 1.71$, $p = .092$, $d = .05$).

There was also a significant three-way interaction between two personality traits (extroversion and neuroticism) of the robots and the gender of the participants in topics concerning *reasons to live* ($F(1,51) = 6.18$, $p = .016$, ${\eta_p}^2 = .11$). Then, we performed a simple interaction test in this topic. For male participants, a marginally significant interaction was found between two personality traits of robot (extroversion and neuroticism) ($F(1,51) = 3.82$, $p = .056$, ${\eta_p}^2 = .14$), whereas no significant interaction was found in female participants ($F(1,51) = 2.58$, $p = .11$, ${\eta_p}^2 = .086$). For more detail, t-tests showed that male participants self-disclosed deeper to HE+HN robot ($M^* = 3.94$, $SD^* = 1.56$) than to LE+HN robot (matched to the LE+HN participants, $M^* = 3.65$, $SD^* = 1.63$; $t(51) = 1.91$, $p = .061$, $d = .18$). At the same time, in this condition, male participants self-disclosed deeper to LE+LN robot ($M^* = 4.07$, $SD^* = 1.71$) than to the LE+HN robot ($t(51) = 2.76$, $p = .008$, $d = .25$) (right in Fig. 4.3).

4.3.5 LE+LN Participants

The marginal means of the depth of self-disclosure obtained from the LE+LN participants are shown in Fig. 4.1 (d). There was a significant main effect of the neuroticism trait of the robots: the depth of self-disclosure to LN (low neuroticism) robots was larger than the case with HN (high neuroticism) robots in topics concerning *health* ($F(1,36) = 6.27$, $p = .017$, ${\eta_p}^2 = .15$). There was also a significant main effect of the gender of the participants: the depth of self-disclosure in female participants was larger than that in male participants in the *health* topics ($F(1,36) = 5.36$, $p = .026$, ${\eta_p}^2 = .13$).

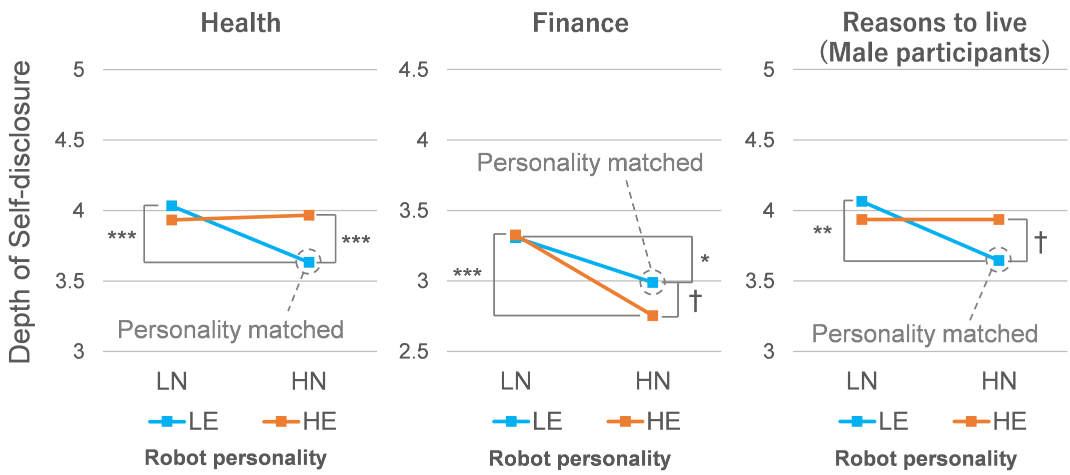

Fig. 4.3 Matching robot personality to participants having low extroversion and high neuroticism (LE+HN participants).

4.3.6 Self-esteem of Participants

Correlation coefficients were calculated between the scores of self-esteem and personality traits of participants. Significant correlations were confirmed ($p < .001$); extroversion: $r = .31$, and neuroticism: $r = .47$. A one-way ANOVA showed a significant difference in the scores of self-esteem between the personality traits ($F(3, 585) = 35.7$, $p < .001$, $\eta_p{}^2 = .16$). Then, from a Tukey HSD analysis, we found that the scores of self-esteem divided by the four participant-groups were ranked as $LE + HN < HE + HN < LE + LN < HE + LN$ ($p < .05$).

4.4 Discussions

4.4.1 Effects of Personality Matching

The results obtained from the HE+HN participants (Section 4.3.2) show that the participants in this group self-disclosed deeper to LN robots than to HN robots in topics concerning *health* and *reasons to live*. In addition, if their personality traits (HE+HN) match the ones of the robot (HE+HN robot), the self-disclosure of the participants was suppressed in *isolation* topics. Therefore, we can interpret that, in this group (except the case with *finance* topics), the depth of self-disclosure decreased due to a similarity-repulsion effect, which supports the hypothesis **H2b**.

Eysenck's portrayal of a person having high neuroticism was *"anxious and afraid when confronted with social situations, seeks to avoid them in order to escape from this* *negative feeling, but frequently wishes that he could be more sociable"* [37]. This negative feeling may weaken their self-esteem. In fact, the results reported in Section 4.3.6 can be interpreted that participants having higher neuroticism had a lower self-esteem. The similarity-repulsion could have arisen from this negative feeling in watching the robot.

The results obtained from the HE+LN participants (Section 4.3.3) show that the participants in this group self-disclosed deeper to LN robots than to HN robots in topics concerning *health*, *finance*, and *isolation*. In addition, if their personality traits (HE+LN) match the ones of the robot (HE+LN robot), the self-disclosure of the participants was increased in *reasons to live* topics. Therefore, we can interpret that, in this group, the depth of self-disclosure increased due to a similarity-attraction effect, which supports the hypothesis **H2a**.

The results obtained from the LE+HN participants (Section 4.3.4) show gender differences: in two kinds of topics concerning *health* and *finance*, female participants self-disclosed deeper than male participants. Plus, the participants in this group self-disclosed deeper to LN robots than to HN robots in topics concerning *isolation*. In the other topics, the results showed complicated interactions as summarized in Fig. 4.3: similarity-repulsion was observed in *health* topics, whereas results were mixed in *finance* topics. Furthermore, in *reasons to live* topics, again, there was a gender difference, a three-way interaction between personality traits of the robots and the gender of the participants. Therefore, we can interpret that, in this group (except the case with *finance* topics and some cases with female participants), the depth of self-disclosure decreased due to a similarity-repulsion effect, which supports the hypothesis **H2b**.

Again, according to the Eysenck's portrayal of a person having high neuroticism, the person was *"anxious and afraid when confronted with social situations, seeks to avoid them in order to escape from this negative feeling, but frequently wishes that he could be more sociable"* [37]. Plus, it was discussed that there was a difference between extroverts and introverts in the degree of craving excitement in social situations [38]. Therefore, introverts may not expect their subjective rewards such as excitement or pleasure obtained through interacting with robots, compared to extroverts. The LE+HN participants were introverted and they could have flexibly changed their behaviors (self-disclosure) according to the type of robots and topics, so that they had not been hurt.

Finally, in the LE+LN participants group (Section 4.3.5), significant differences were found only in *health* topic: the participants self-disclosed deeper to LN robots

Table 4.3 The results summary of the study, together with recommendations for designing the personality traits of mediator robots.

Topic		User's Personality Traits			
		HE+HN	HE+LN	LE+HN	LE+LN
Health	Matching Effect	-	-	Repulsive	-
	Recommended Design	LN	LN	Unmatched	LN
Finance	Matching Effect	-	-	Mixed	-
	Recommended Design	-	LN	LN	-
Isolation	Matching Effect	Repulsive	-	-	-
	Recommended Design	Unmatched	LN	LN	-
Reasons to live	Matching Effect	-	Attractive	Repulsive (male)	-
	Recommended Design	LN	Matched	Unmatched (male)	-

than to HN robots, and female participants self-disclosed deeper than male participants. Overall, in this participants group, the depth of self-disclosure was not much affected by robot personality, which could have been due to the emotional stability (low extroversion and low neuroticism) of the participants. The participants in this group were also introverted, and they might have been felt little excitement in interacting with the robots. At the same time, because their neuroticism was also low, they might have had little anxiety as well.

To conclude, Table 4.3 summarizes the results of this study, and recommendations for designing the personality traits of mediator robots, which answers to the research question in this Chapter 4, "How the robot's character should be personalized to the elderly user?" In previous HRI studies, matching robot personality to the user had been discussed mainly in single dimension (especially extroversion) [3, 86, 99, 158, 7]. In contrast, the present study made a further detailed investigation involving extroversion, neuroticism, and human gender.

In this study, we discussed personality factors between mediator robots and the users, and then we reported detailed findings as well as recommendations as to designing the personality traits of the mediator robots (Table 4.3). On the other hand, we often reported main effects concerning the neuroticism trait of the mediator robots. Overall, the results show that participants self-disclose deeper to LN robots than to HN robots. Low neuroticism may be a trait that is generally effective for mediator robots. In contrast, we could not find so many main effects as to the extroversion trait of mediator robots compared to the neuroticism trait.

The results of this study also show that the personality traits of participants may greatly affect the HRI discussed in this study. For example, we observed a very few effect in the LE+LN participants group. The study suggests that when measuring human self-disclosure, we should take into consideration multiple personality traits of participants.

4.4.2 Gender Factors of Disclosers

We conducted a follow-up study about gender differences in participants. Following the literature in computer-mediated communications (CMCs) [4], we compared the participants' depth of self-disclosure between a robot condition and a face-to-face condition. In the robot condition, participants were instructed to use a mediator robot in self-disclosure, whereas in the face-to-face condition, participants were instructed to talk to a human recipient face-to-face.

We collected data from the participants (N=589), and measured their depth of self-disclosure across the two conditions. In the robot condition, participants watched a short video in which a recipient person receives a message from the Type-A robot (Section 3.2.2).

A 2×2×2 split-plot factorial ANOVA having a within-participant factor (robot/face-to-face) and two between-participant factors, participant's gender (male/female) and recipient types (family/friend), was conducted on four kinds of topics (*health*, *finance*, *isolation*, and *reasons to live*) and two personality traits (HN/LN) of the participants.

In the HN participants group, there was a significant interaction between conditions and gender in topics concerning *reasons to live* ($F(1, 81) = 3.97$, $p = .050$, ${\eta_p}^2 = .047$). Post hoc comparisons using t-tests showed a significant difference in the average depth of self-disclosure of the male (HN) participants between the robot condition ($M^* = 4.22$, $SD^* = 1.45$) and the face-to-face condition ($M^* = 3.47$, $SD^* = 1.45$; $t(81) = 3.00$, $p = .004$, $d = .52$), and a marginally significant difference between female (HN) participants ($M^* = 4.06$, $SD^* = 1.44$) and male (HN) participants in the face-to-face condition ($t(162) = 1.87$, $p = .063$, $d = .41$) (Fig. 4.4, left).

There were also significant three-way interactions between conditions, gender, and recipient types in topics concerning *health* ($F(1, 53) = 5.34$, $p = .025$, ${\eta_p}^2 = .091$) and *isolation* ($F(1, 71) = 4.62$, $p = .035$, ${\eta_p}^2 = .061$) in the HN participants group. Simple interaction tests showed a significant interaction between conditions and recipient types in male (HN) participants in topics concerning *health* ($F(1, 31) = 4.10$, $p = .048$, ${\eta_p}^2 = .095$), and another significant interaction between conditions and recipient types in female (HN) participants in topics concerning *isolation* ($F(1, 33) = 6.25$, $p = .015$, ${\eta_p}^2 = .18$). Then, in topics concerning *health*, it was found that male (HN) participants self-disclose deeper to family recipients in the robot condition ($M^* = 4.86$,

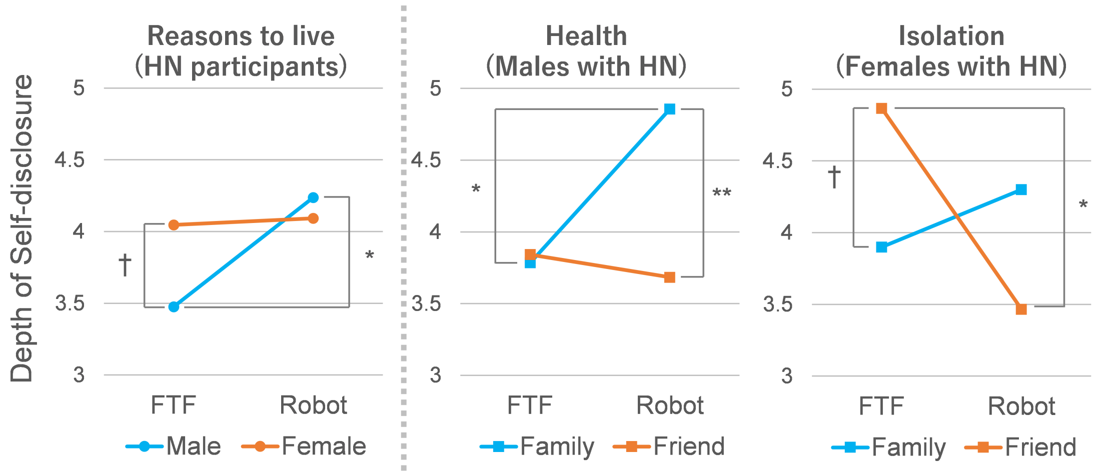

Fig. 4.4 Gender differences in disclosers regarding the depth of self-disclosure. (FTF: face-to-face condition, Robot: robot condition)

SD^* = 1.56) than in the face-to-face condition (M^* = 3.79, SD^* = 1.61; $t(53)$ = 2.33, p = .024, d = .68), and also they self-disclose deeper to family recipients than to friend recipients (M^* = 3.68, SD^* = 1.56; $t(53)$ = 2.73, p = .009, d = .75) in the robot condition (Fig. 4.4, center). In contrast, in topics concerning *isolation*, female (HN) participants self-disclose deeper to friend recipients in the face-to-face condition (M^* = 4.87, SD^* = 1.65) than in the robot condition (M^* = 3.47, SD^* = 1.67; $t(71)$ = 2.57, p = .012, d = .84), and also they tend to self-disclose deeper to friend recipients than to family recipients (M^* = 3.90, SD^* = 1.65) in the face-to-face condition ($t(71)$ = 1.90, p = .062, d = .59) (Fig. 4.4, right).

The results show some opposite tendencies between male and female participants. We may interpret the results as suggesting that the mediator robot is the most effective for male participants having high neuroticism (HN) in dialogue topics concerning *reasons to live*, and *health* (to family recipients). Also, the mediator robot may not be that effective for female participants having high neuroticism (HN) in a dialogue topic concerning *isolation*. On the other hand, for the LN participants group, no significant effect was found in any factor.

4.4.3 Limitations and Future Works

Across two studies reported in this chapter, a fundamental limitation exists in that both the studies lack a behavioral measurement of self-disclosure. We used questionnaires and did not directly measure the disclosing behaviors (i.e., utterances, etc.) of participants. In addition, all measurements were conducted within relatively short time windows. Another big issue was that our studies depended on simulated conversation scenarios. In addition, the scripts we used were just an example and we can not claim generality. In this study, video stimuli were also used. Empirical HRI studies are awaited to strengthen the results of those studies. Finally, all participants in these studies were Japanese. There must have been some cultural factors that might have affected the results.

The studies reported in this chapter mainly discussed mediator robots and disclosers. Further studies are needed to take the recipient side into consideration. In fact, there were such comments from participants as *"I think I cannot tell such a trouble to my friend. I'm worried if the robot could separate my friend from me."* or *"I feel telling my trouble through this robot might be rude for my daughter."* These comments imply a need for designing social mediator robots by considering not only the discloser side but also the recipient side.

Chapter 5

How Should Social Mediator Robot Deliver Messages of the Elderly?: A Large-Scale Exploratory Study

Having promise as a new communication tool preventing elderly people from being socially-isolated, the design guideline of the social mediator robot has been investigated. Then, it became clear that depending on the topic of a remote conversation between elderly users and their recipients, the proper design of the social mediator robot becomes different. Personality traits of the elderly users such as high/low extroversion and high/low neuroticism, and types of the recipients such as family members and friends also affected the design. The design guidelines proposed in the previous chapters summarized all those requirements for the social mediator robot at the elderly's side (left in Fig. 1.1). However, there has been no investigation made so far about the way of messaging in the side of recipients (right in Fig. 1.1). It is deeply related with self-presentation [10] that was defined as "*how people attempt to present themselves to control or shape how others view them.*" Self-presentation refers part of a broader set of behaviors called impression management. Here, the way of messaging by the two mediator robots, i.e., how those robots convey messages obtained from the elderly side to the recipient side concerns the self-presentation, and, most importantly, it affects the interpersonal effects of self-disclosure.

The goal of this chapter is to answer to the research question, "What types of behaviors should mediator robots have to report the messages effectively?" To promote the self-disclosure of elderly people, it will be important to decrease their anxiety in disclosing their messages. Among huge varieties of human anxiety, the one particularly perceived in interpersonal situation is called social anxiety

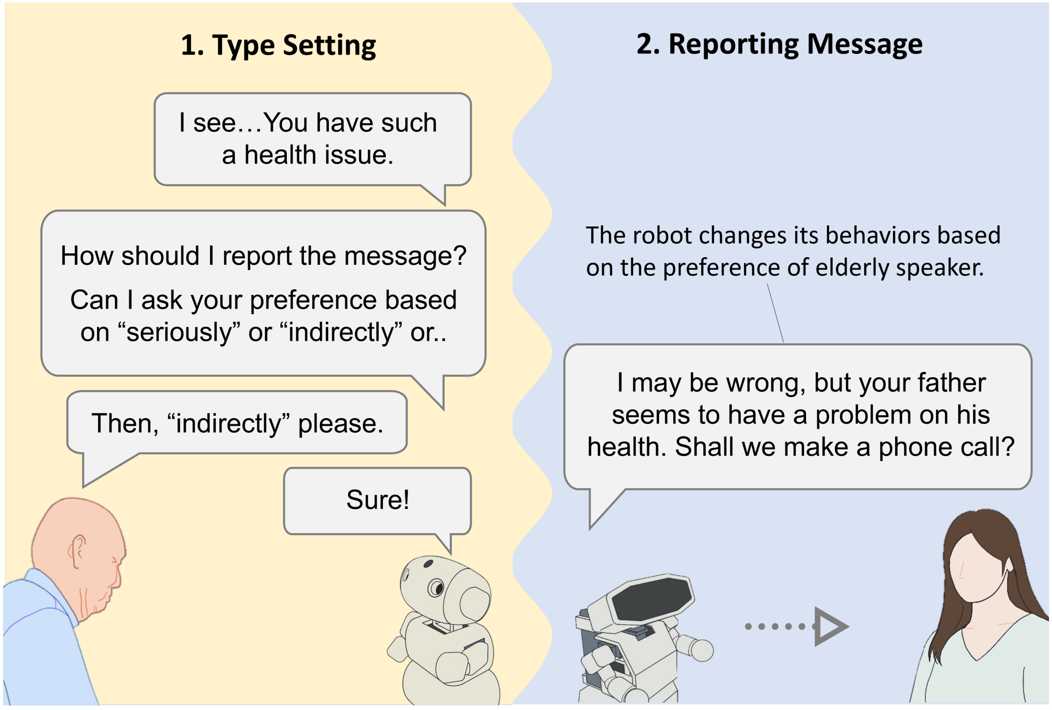

Fig. 5.1 A human-robot interaction assumed in this study for defining behaviors in reporting user messages. At first, the elderly-side robot offers several messaging options after it listened to the elderly's self-disclosure. In this example, the "indirectly" was chosen by the elderly user. According to these information, the recipient-side robot reported the message in indirect way.

(SA) [84]. The level of SA can be represented as a function of the motivation level of self-presentation (M) and a self-presentation efficacy (p): $SA = f\{M \times (1 - p)\}$. As the equation indicates, the self-presentation efficacy (p) has to be increased to decrease the level of social anxiety (SA). To increase the self-presentation efficacy of elderly disclosers, the robot should have multiple messaging options (the ways of messaging) to support their self-presentation. Then, each elderly discloser can choose a messaging option depending on his/her preference at the time of each messaging. For example, if an elderly discloser wants the mediator robot to tell his/her message to a recipient in a soft and indirect way, the robot could add some words or phrases accordingly (Fig. 5.1).

To identify effective messaging options, first, we referred specific emotions generating avoidance of self-disclosure. In the field of psychology, it is known that certain feelings (such as interpersonal/intrapersonal anxiety or hopeless) exist, which are associated with reluctance to self-disclose. By designing the robot behaviors so as to mitigate those feelings, the elderly self-disclosure could be encouraged.

However, few studies investigated those feelings particularly perceived in the elderly self-disclosure. Thus, in this study, we attempted to identify them through a two-phased preliminary survey. By following the survey results, we then created 15 candidates of messaging options. The preference for each candidate was asked to N = 528 participants through an online based large-scale exploratory study. The objective of this study is to filter the candidates, and have useful detailed design knowledge depending on factors such as the gender and the personality traits of elderly disclosers, recipient types (family members/friends), and conversation topics. Thus, in this chapter, we did not measure the anxiety that the elderly people actually perceived during self-disclosure. In the next chapter, this effect will be investigated through a physical HRI study.

5.1 Preliminary Survey: Phase 1

To identify specific feelings that elderly people have when disclosing their *loss experience* to other people (recipients), an online survey was conducted (N = 108). In this survey, the participants were presented with a list of 21 words that describe their emotions and feelings. They were then asked to choose one that they might recall when self-disclosing on a particular topic.

5.1.1 Participants

104 participants aged over 65 years (all Japanese, M = 70.6 years old, SD = 4.89, 50% male, 50% female) were recruited through the panel of MACROMILL, Inc. which is a leading market research company in Japan. The target participants were "persons who are communicating with their own children and intimate friends at least once in three years by phone or face to face."

We assumed two types of recipients (family/friend). A family recipient was defined as a family member in young generations who communicated with the participant the most. A friend recipient was defined as an intimate friend for over ten years who communicated with the participant the most. The reasons for dividing recipients were (1) relationships between disclosers and recipients is known to be an important factor when disclosers determine the breadth and the depth of topics they discuss [2], and (2) social supports to be requested to family members can be different from ones to friends [80]. Family recipients chosen by the participants were daughters (55.8%), sons (34.6%), female grandchildren (5.8%), sons' wives

(2.9%), and the others (1.0%). The 50% of the recipients had the same gender as the participants. Friend recipients chosen by the participants had an average age of 69.9 years (SD = 7.81) and the 97% of them had the same gender as the participants.

To have a better awareness of each recipient during the survey, all participants were asked to complete forms with initials of the recipients. For this survey, each participants imagined both types of the recipients (within-participant factor). The fieldwork period was from October 27th to October 29th in 2017 and was conducted by MACROMILL, Inc.

5.1.2 Procedure

First, participants were asked their experience (yes/no) on eight topics (four from *loss experience*[1], and four from *everyday and integrated life experience*[2]). The latter four topics about *everyday and integrated life experience* were brought from [153] and used just for comparison.

Then, for each topic on which they had experience, they were asked "What kinds of feelings do you have if you disclose this topic with the recipient in face-to-face conversation?" with 21 words representing feelings presented. The participants were able to choose an arbitrary number of those words, if applicable. The 21 words were derived from two references in psychology: joy, trust, fear, surprise, sadness, self-disgust, anger, anticipation from [125][3], anxiety, like, hopeless, guilt, despair, shame, inferiority, pessimism, happiness, disappointment, fulfillment, isolation, and alienation from [116].

5.1.3 Results & Discussions

Table 5.1 presents seven words that were chosen significantly by the participants. Particularly, on *loss experience* topics, two feelings (anxiety and hopeless) were chosen significantly. Therefore, the study revealed that "anxiety" and "hopeless" are two representative negative feelings that elderly people typically have in disclosing their *loss experience* to other people. There was no significant difference between the recipient types.

[1]The four topics were: *health* (N = 75), *finance* (N = 41), *isolation* (N = 30), and *reasons to live* (N = 18).

[2]The four topics were: *places I'd like to visit and things I would like to try* (N = 92), *recent happy events and interesting TV programs* (N = 78), *beliefs and wisdom gained in my life* (N = 88), and *unforgettable memories and my history* (N = 88).

[3]To be exact, the eight words should be for emotions.

Table 5.1 Seven words chosen significantly by the elderly participants for two kinds (*loss experience* and *everyday and integrated life experience*) of topics.

	(a) To family recipients			(b) To friend recipients		
words	loss experience	everyday and integrated life experience	χ^2	loss experience	everyday and integrated life experience	χ^2
anxiety	**44***	8	72.4	**48***	4	95.2
hopeless	**28***	9	34.3	**31***	11	35.0
joy	3	**99***	50.1	2	**72***	34.6
like	3	**52***	20.3	11	**68***	14.4
anticipation	13	**68**	11.6	8	**64**	17.2
happiness	5	**70***	26.4	1	**70***	35.9
fulfillment	9	**87***	28.3	6	**78***	29.0

all $df = 1$, **$p < .01$, ***$p < .001$

Concerning "anxiety" toward self-disclosure, there discussed in psychology two types of aversions depending on their directions (intrapersonal or interpersonal) [71]. As to the intrapersonal aversion, negative feelings tend to be promoted when disclosing negative emotions [26], and self-evaluation comes down due to a perception of negative aspects of disclosers by themselves [11]. As to the interpersonal aversion, disclosing negative topics can weaken relationships between recipients [51], and can be annoyed even within close people.

Concerning "hopeless" toward self-disclosure, it can lead to the denial of receiving support from other people. Usually, self-disclosure can trigger the facilitation of social support from recipients [24]; however, if disclosers give up solving their troubles by receiving social support from recipients, they could stop their self-disclosure. In social support researches for elderly people, there have been discussed emotional support and material support provided from caregivers [80, 143, 60].

By using the two different anxiety feelings concerning intrapersonal and interpersonal aversion as well as two different hopeless feelings concerning emotional and material support, in the next section, we will further advance the study.

5.2 Preliminary Survey: Phase 2

The objective of this survey is to detect the specific situations in which elderly people perceive anxiety and hopeless in self-disclosure. More specifically, the situations comprise the following elements:

- Topics of self-disclosure: *health*, *finance*, *isolation*, and *reasons to live*
- Recipient type: *family* or *friend*
- Discloser's gender: *male* or *female*

In addition, we explored what kind of anxiety and hopeless the elderly disclosers have in each situation. To do so, we developed a scale to measure anxiety and hopeless in detail, based on the results and discussions of the previous section. The results of this study will be used to design appropriate behaviors for the mediator robot.

5.2.1 Participants

416 participants aged over 65 years (all Japanese, M = 69.5 years, SD = 3.82, 50% male, 50% female) were recruited through the panel of MACROMILL, Inc. We had 104 participants for each of the four topics related to *loss experience*. The target profiles of participants in the recruitment were: (1) persons who were communicating with their own children and intimate friends at least once in three years by phone or face to face; (2) persons who were living alone or with their spouses only; (3) persons who had own troubles regarding either of loss experience topics (health, financial, isolation, and reasons to live[4]) that had never been disclosed to other people. To exclude participants who did not meet those requirements, a screening process was carried out before proceeding to the main survey.

In addition, following the previous survey, two types of recipients (family/friend) were assumed. Family recipients chosen by the participants were daughters (51.2%), sons (40.7%), sons' wives (4.29%), female grandchildren (1.67%), and male grandchildren (1.19%). The 52% of the recipients had the same gender as the participants.

[4] In the questionnaire, we asked: do you have experiences regarding; troubles concerning your own health and illness (health); troubles concerning living income and savings (finance); troubles concerning people whom you can depend on disappearing and you become alone (isolation); you cannot feel reasons to live (reasons to live)

Friend recipients chosen by the participants had an average age of 68.2 years (SD = 6.49) and the 93% of them had the same gender as the participants.

All participants were asked to complete forms with initials of the recipients. For this survey, each participants imagined both types of the recipients (within-participant factor). The fieldwork period was from December 27th to December 28th in 2017 and was conducted by MACROMILL, Inc.

5.2.2 Scale Development

Based on our survey and insights brought from psychological studies concerning aversions in self-disclosure [71], we created 18 question items for measuring the elderly's anxiety and hopeless in self-disclosure (the question items are shown in Table 5.2). First 10 items were designed for measuring anxiety (concerning intrapersonal or interpersonal aversion) and last 8 items were designed for measuring hopeless (for emotional or material support). When in use, each participant was assumed to be instructed to imagine a situation in which he/she disclose his/her trouble to a conversation partner face-to-face, and then assess the question items by using a scale of "1: very unlikely to feel" to "6: very likely to feel."

5.2.3 Results

After checking the validity of the scale thorough an exploratory factor analysis (EFA), we performed 2×2 split-plot factorial ANOVA on each factor of feelings, with the factors of the gender of the participants (between-participants factor) and the type of recipients (within-participant factor) in each of four topics.

Scale Validity

We performed an EFA on the participants' perception of feelings by using the maximum likelihood method with a promax rotation. The factor analysis revealed three factors with eigenvalues greater than one, and the scree plot indicated a clear leveling-off point after the third factor (Fig. 5.2). In addition, these three factors accounted for 65.6% of the overall variance in the perception of the feelings. Table 5.2 listed factor loadings of each item loaded onto the three factors (factor loading > .40). Here, cross loading items were not found[5].

[5] To obtain a simple structure, (Q4) and (Q6) were removed whose factor loading were greater than .35 for more than two factors.

Table 5.2 Questionnaire items for measuring anxiety and hopeless of elderly people in disclosing their loss experience. Values of the factor loading for each factor (I/II/III) were also shown next to the corresponding question items. The items having none of the values for factor loading were eliminated in the validation process.

	Question items	I	II	III
Q1	If I talk, I may realize the trouble again and feel unpleasant.	**.721**	-.097	.194
Q2	After the conversation, I feel miserable.	**.753**	-.105	.225
Q3	After the conversation, I think of myself useless.	**.900**	-.217	.109
Q4	I will regret that I should not have talked on this topic.			
Q5	By telling this story to the partner, I feel uneasy to get hurt.	**.899**	-.085	.025
Q6	I will be disliked by the partner by my talking.			
Q7	If I talk on this topic, the partner will be annoyed.	**.565**	.270	-.018
Q8	The partner will have a negative image of me.	**.763**	.242	-.168
Q9	I will be put in a vulnerable position against the partner.	**.686**	.217	-.133
Q10	I become anxious that I may be disliked by the partner if I talk on this topic.	**.750**	.227	-.169
Q11	Even if I talk on this topic, the partner will not listen to me kindly.	-.086	**.810**	.097
Q12	Even if I talk on this topic, the partner will not encourage me.	.004	**.723**	.053
Q13	The partner will not respect my feelings and thoughts anyway.	.069	**.700**	.104
Q14	The partner will not listen to me well anyway.	.015	**.845**	-.024
Q15	I feel hopeless because even if I talk to the partner, my feelings will never be understood.	.190	**.449**	.304
Q16	Even if I talk to the partner, he/she will not solve my trouble instead of me.	-.101	.229	**.672**
Q17	Even if I talk to the partner, he/she cannot do anything for me.	.006	-.024	**.761**
Q18	I feel hopeless because even if I talk to the partner, I will not get any help to solve my trouble.	.113	.124	**.685**

The first factor was labeled *Anxiety concerning interpersonal/intrapersonal aversion.* This factor consisted of eight items; e.g., "(Q3) After the conversation, I think of myself useless." and " (Q8) I will be put in a vulnerable position against the partner." (Cronbach's α = .93). Anxiety concerning intrapersonal aversion and anxiety concerning interpersonal aversion had high communality and were extracted as an identical factor.

The items loaded onto the second factor related to denial for receiving effective emotional support from the recipients, and we labeled this factor *Hopeless for emotional support.* This factor consisted of five items; e.g., "(Q14) The partner will not listen to me well anyway." and "(Q11) Even if I talk on this topic, the partner will not listen to me kindly." (Cronbach's α = .89).

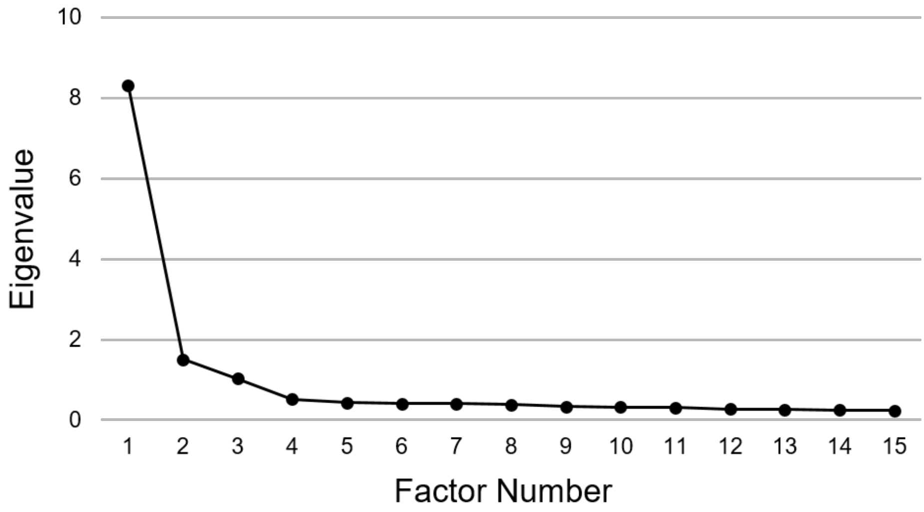

Fig. 5.2 Scree plot (preliminary survey: phase 2)

Factor 3 items were related to denial for receiving effective material support from the recipients, and we labeled this factor labeled *Hopeless for material support.* The items that comprised this factor were: e.g., "(Q17) Even if I talk to the partner, he/she cannot do anything for me.", "(Q16) Even if I talk to the partner, he/she will not solve my trouble instead of me." (Cronbach's α = .83).

In addition to the all of the those factors had relatively high scale reliability (all $\alpha > .82$), the items which comprised each factor were semantically consistent with each other. We conclude that these items can be used as a valid scale to measure the negative feelings of elderly people in disclosing loss experience.

Situation in Which Anxiety Concerning Interpersonal/Intrapersonal Aversion Promoted

There were no main effects of the gender of the participants and type of recipients in all topics. There was a significant interaction between the gender of the participants and type of recipients in a topic concerning *finance* ($F(1, 102) = 6.44$, $p = .013$, $\eta_p{}^2 = .059$). A simple interaction test indicated that male participants felt this feeling to the friend recipients stronger than to the family recipients ($t = 3.25$, $p = .002$ $df = 204$). At the same time, to the friend recipients, male participants felt this feeling stronger than the female participants ($t = 5.25$, $p < .001$ $df = 102$).

Situation in Which Hopeless for Emotional Support Promoted

There were significant main effects of type of recipients in two topics: participants felt this feeling to family recipients stronger than to friend recipients in topics concerning *isolation* ($F(1, 102) = 7.61$, $p = .007$, ${\eta_p}^2 = .069$) and *reasons to live* ($F(1, 102) = 7.31$, $p = .001$, ${\eta_p}^2 = .067$). There also be significant main effects of the gender of the participants in the above two topics: male participants felt this feeling stronger than female participants in topics concerning *isolation* $F(1, 102) = 5.56$, $p = .020$, ${\eta_p}^2 = .052$ and *reasons to live* $F(1, 102) = 3.45$, $p = .066$, ${\eta_p}^2 = .033$).

Situation in Which Hopeless for Material Support Promoted

There were significant main effects of type of recipients in two topics; participants felt this feeling to the friend recipients stronger than family recipients in topics concerning *health* $F(1, 102) = 7.97$, $p = .006$, ${\eta_p}^2 = .072$ and *finance* $F(1, 102) = 11.7$, $p = .001$, ${\eta_p}^2 = .10$). There also be a marginal significant interaction between the gender of the participants and type of recipients in a topic concerning *health* ($F(1, 102) = 3.69$, $p = .057$, ${\eta_p}^2 = .035$). A simple main effect test indicated that the female participants felt this feeling stronger to friend recipients than to family recipients ($t = 3.35$, $p = .001$ $df = 102$).

5.2.4 Discussion

The first factor was interpreted as "anxiety concerning interpersonal/intrapersonal aversion," and the feeling of male disclosers were promoted when they discuss financial issues with their friends compared to female disclosers. Here, the differences in gender roles in Japanese families have been historically contextualized and remain complete stereotypes as males should earn money from outside and females should do housework [114, 91]. Such stereotypes may enhance an elder male's subjective importance to earning an income, and their difficulties with sharing the loss of financial foundations among same-generational friends. In other words, males may be avoiding self-disclosure of financial issue to their friends in order to protect their pride. In order to avoid hurting pride of the elderly disclosers, social mediator robot should regulate information when it reports their messages. For examples, robot behaviors such as masking negative emotions which the disclosers having or anonymizing the contents what the disclosers told, while reporting the messages.

The factor 2, "hopeless for emotional support" was perceived by male and female participants when they discuss with their family recipients in topics concerning *isolation* and *reasons to live*. Conversely, the third factor “hopeless for material support” was strongly perceived when male and female participants discuss with their friend recipients in topics concerning *health* and *finance*. By following a social support study [80], the type of social support and its source are corresponded to each other. Therefore, these feelings could be promoted when the recipients were inconsistent persons to be a source of each support. Together, male disclosers tended to feel hopeless stronger than female disclosers. For the elderly users who avoid self-disclosure due to the hopeless for getting social support, robot behaviors so as to facilitate supports from the recipients may be useful. For example, the robot can emphasize negative emotions of the disclosers or directly asks for recipients to help the disclosers.

5.3 Main Study

Based on the insights brought by our two-phased preliminary survey, first, we introduce the candidates of messaging options (shown in section 5.3.1). After that, an online survey was conducted to explore (1) which messaging options that the social mediator robot should have and (2) differences in the preference for each messaging option according to the situation. More specifically, the situations comprise the following elements:

- Topics of self-disclosure: *health*, *finance*, *isolation*, and *reasons to live*
- Recipient type: *family* or *friend*
- Discloser’s gender: *male* or *female*
- Discloser’s personality traits: *high neuroticism* or *low neuroticism*

The authors’ previous study revealed that the neuroticism trait[6] of disclosers significantly affect the depth of self-disclosure in using social mediator robot (the work reported in Chapter 4). More specifically, when a social mediator robot was used, male participants with high neuroticism would self-disclose deeply more than on face-to-face condition in some topics. Also, following the study on

[6]Neuroticism trait is one of the personality traits of Big Five Personality model [65]. According to Eysenck’s portrayal of a person with high neuroticism was “anxious and afraid when confronted with social situations, seeks to avoid them in order to escape from this negative feeling, but frequently wishes that he could be more sociable [37].” It is also known that neuroticism negatively correlates with self-esteem of persons [5] that was also used for a predictor of the adaptation levels of elderly people [30].

computer-mediated communications (CMCs) [4], people with high neuroticism tend to like CMCs than people with low neuroticism. Therefore, in this study we also investigated differences in the neuroticism trait of disclosers.

5.3.1 Design of the Messaging Option

Several guidelines for designing robot behavior were obtained through the two-phased preliminary survey. First of all, the robot may need to have behaviors which enable the user can regulate information when it reports the messages. As the instance of these behaviors, following three messaging options were created (the part written as (DISCLOSER) can be replaced by the name of the elderly discloser, and the part written as (MESSAGE) can be replaced by the elderly's original message which is listened by the robot. XX can be replaced by short terms representing the topics of MESSAGE):

- **Report the message to the recipient as just a speculation of the robot while concealing that the user disclosed his/her troubles;** when it speaks, the script is like "Maybe I'm thinking too much, but I guess (DISCLOSER) is in trouble about XX recently."
- **Report the message to the recipient as a common trouble of elderly people while concealing that the user disclosed his/her troubles;** when it speaks, the script is like "By the way, it seems there are many elderly people who are in trouble about XX. But I heard that it is hard for them to say from their mouth."
- **Report the message to the recipient without saying true emotions of the elderly discloser;** when it speaks, the script is like "(DISCLOSER) said that there is nothing troublesome and he/she is doing well, but if he/she was forced to say something, (DISCLOSER) said that (MESSAGE)."

On the other hand, robot behaviors that could facilitate mental/material social supports from the recipients may be useful particularly for the elderly users who perceive hopeless in their self-disclosure. As the instance of these behaviors, following three messaging options were created:

- **Ask the recipient to help the trouble of the discloser, not just report the message;** when it speaks, the script is like "(DISCLOSER) said that (MESSAGE). I know you are very busy, but would you please help (DISCLOSER)? I hope you help him/her."

- **Tell the recipient that other elderly people are being helped by their family members and friends, not just report the message;** when it speaks, the script is like "(DISCLOSER) said that (MESSAGE). There are a lot of elderly people who have such troubles, but it seems that the number of families and friends who support them are increasing."

- **Emphasize discloser's current feeling that he/she is suffered by the troubles when it reports the message to the recipient;** when it speaks, the script is like "I heard that (DISCLOSER) had (discloser's emotion like sad) events. Then, he said that (MESSAGE)."

In addition, six messaging options were also created from the view point of the personality traits of the robot at the recipient side. This may also influence the self-disclosure of the elderly people. In designing these options, we referred three personality traits (extroversion, conscientiousness, and neuroticism) chosen from the Big Five personality model[7]. Based on the those personality aspects, the following options were created that can be used together with the verbal behaviors introduced above.

- **Lively;** when speaking, the robot uses a lively tone of the voice.

- **Calmly;** when speaking, the robot uses a low tone of the voice.

- **Seriously;** when reporting the message, the robot behaves seriously.

- **Informally;** when reporting the message, the robot behaves informally.

- **Anxiously;** when reporting the message, the robot tells the recipient about the discloser's problem in a way that the robot itself is worried about that.

- **Optimistically;** when reporting the message, the robot tells the recipient about the discloser's problem in a way that the robot has optimistic thinking on that.

Lastly, the number of nonverbal cues also may affect self-presentation, especially in settings of computer-mediated communication [167]. Therefore, three messaging options are created representing the messaging format which contains different amount of non-verbal information.

[7] In this study, agreeableness and openness traits were not compared in each level (high/low). This was because; for agreeable traits, we could assume that the robot with low agreeable robot is not suitable for mediator role in any situations. For openness traits, due to the few knowledge on how to design a robot having high/low openness trait, it is hard to explain the feature clearly to the older participants. Thus, we decided to exclude this factor from our study.

- **Report the message as it is;** when reporting the message, the robot reads out the original contents what the discloser spoke, by using its voice.
- **Report as a voice message;** the robot records the voice of the elderly discloser and plays it at the recipient side.
- **Report as a video message;** the robot records the video of the elderly discloser and plays it at the recipient side.

5.3.2 Participants

Participants for this study were recruited through the panel of MACROMILL, Inc. which is a leading market research company in Japan. Initially, we obtained 720 participants over 65 years (all Japanese, M = 69.8 years, SD = 4.11, 50% female and 50% male). However, we excluded data obtained from 131 participants who were not confident in understanding all the survey procedure (measured by a question item), and therefore data from 589 participants were used in analyses in the end. The fieldwork period was from December 17th to December 19th in 2018 and was conducted by MACROMILL, Inc.

The target profiles of participants in the recruitment were: (1) persons who were communicating with their own children and intimate friends at least once in three years by phone or face to face; (2) persons who were living alone or with their spouses only; (3) persons who had own troubles regarding either of loss experience topics (health, financial, isolation, and reasons to live[8]) that had never been disclosed to other people. To exclude participants who did not meet those requirements, a screening process was carried out before proceeding to the main survey.

Also, we assumed two types of recipients (family/friend). A family recipient was defined as a family member in young generations who communicated with the participant the most. A friend recipient was defined as an intimate friend for over ten years who communicated with the participant the most. The reasons for dividing recipients were (1) relationships between disclosers and recipients is known to be an important factor when disclosers determine the breadth and the depth of topics they discuss [2], and (2) social supports to be requested to family members can be different from ones to friends [80].

[8]In the questionnaire, we asked: do you have experiences regarding; troubles concerning your own health and illness (health); troubles concerning living income and savings (finance); troubles concerning people whom you can depend on disappearing and you become alone (isolation); you cannot feel reasons to live (reasons to live)

Each participants imagined one type of the recipients (family of friend, between-participants factor). Family recipients selected by the participants included daughters (50.0%), sons (29.5%), sons' wives (4.5%), and others (< 1.0%). 52% of the family recipients were the same gender as the disclosers. Friend recipients had an average age of 68.3 years (SD = 6.20), and 93% of the recipients selected were the same gender as the disclosers. To have a better awareness of each recipient during the survey, all participants were asked to complete forms with initials of the recipients.

5.3.3 Measurement

Preference for the Messaging Options

To ask the participants about their preference for each candidate of messaging option introduced above, we presented 15 questionnaire items (Table 5.3). When in use, we asked the degree of the agreement toward each question item based on the scale of "1: strongly disagree" to "7: strongly agree". The higher the number marked, the more preferable the behavior of the robot was evaluated by the participants. For the question items from Q1 to Q6, dialog scripts shown in the section 5.3.1 were also presented as the examples for providing better understanding to the participants.

Personality Traits

A Big Five scale [102] was used to evaluate the neuroticism of each participant, which was represented by five items; easy to feel uneasy, anxious mind, get discouraged, easy to get nervous, and depressive. A seven-point scale of "1: strongly disagree" to "7: strongly agree" was used in answering to question items concerning those scales.

Participant's Comprehension

As explained in Section 5.3.2, the participant's comprehension about this survey was checked by using the two questions: "I could not understand some video contents." and "I could not understand how the mediator robot works." The participant could assess his/her comprehension based on a seven-point scale of "1: strongly no" to "7: strongly yes." Results data obtained from participants who marked a 5-7 on either/both questions were excluded from analyses.

Table 5.3 Questionnaire items used for measuring the preference of the elderly disclosers for the message options.

	Question items
Q1	I want the robot to report the message as just a speculation of the robot while concealing that I disclosed the trouble.
Q2	I want the robot to report the message as a common trouble of elderly people while concealing that I disclosed the trouble.
Q3	I want the robot to report the message without saying my suffered or worried feeling.
Q4	I want the robot to ask the recipient to help me with my trouble.
Q5	I want the robot to tell the recipient that other elderly people are being helped by their family members and friends.
Q6	I want the robot to emphasize my current feeling that I am suffered by or worried about the troubles.
Q7	I want the robot to report the message with a lively tone of the voice.
Q8	I want the robot to report the message with a low tone of the voice.
Q9	I want the robot to report the message while displaying serious attitudes.
Q10	I want the robot to report the message while displaying informal attitudes.
Q11	I want the robot to report the message in a way that the robot itself is worried about my trouble.
Q12	I want the robot to report the message in a way that the robot itself has optimistic thinking on my trouble.
Q13	I want the robot to report the message by reading out the one what I talked as it is.
Q14	I want the robot to report the message by using my recorded voice.
Q15	I want the robot to report the message by using my recorded movie.

5.3.4 Procedure

At the beginning, an experimenter explained the basic concept of social mediator robots and the purpose of this survey for each participant. Then, the participants were instructed to watch a short video clip which shows a scene that a recipient person receives a message from a robot[9]. This video was used for introducing participants how the robot tells a message to recipients while showing a simple example. The video clip was taken from the first-person perspective and simulating human-robot conversations (Table 5.4). Although the voices of the robots were recorded, the utterances of a recipient person was presented by subtitles only (no voice). The time length of the video clip was approximately 30s. After that, participants were asked their preference for each messaging option of the robot through the questionnaire,

[9]You can see this video from https://youtu.be/7eyd34K-R0o

Table 5.4 Simulated conversations between a human recipient and a robot shown in the video.

Speaker	Utterance
Robot:	A message has arrived from (YOU). Do you want to check it now?
Recipient:	"Yes, please."
Robot:	OK. This is the message. (YOU) said that "I'm in trouble with XX, and I'd like you to listen to me." If you want to reply to him/her, please tell me.

followed by participants' personality questionnaires. Finally, the overall participant's comprehension about this survey was asked.

5.3.5 Experimental Design and Statistical Analysis

Participants were divided into 2 groups based on their neuroticism trait. Median value obtained from the personality scale divided participants into high/low neuroticism groups (a boundary value was 4.00). The mean value was 4.84 (SD = .56) in the HN (high neuroticism) group, and 3.28 (SD = .62) in the LN (low neuroticism) group. There was a significant difference between them (t = 32.1, p < .001, df = 587). The structure of participants is summarized in Table 5.5.

An EFA was conducted for checking the validity of the scale developed in this study. Then, to filter some messaging options those were not preferred by many participants, we conducted chi-square tests. More specifically, for each item, the number of participants who scored more than 4.0 and those who scored less than 4.0 was compared. Through the analysis, every items can be subdivided into *major options* — items that were preferred by large numbers of participants, *minor options* — items that were preferred by small numbers of participants, and others — items in which there was no difference in the numbers participants. In the comparison, participants who scored 4.0 (neutral) were excluded.

The message options in which there was no significant difference in the number of participants, *detail options*. This is because the preferences for the messaging options classified into this group may vary according to the situation, thus the robot needs to make detailed questions to know the user's the preferences. In this study, the difference of the user's preference by the situation was also attempted to be explored. More specifically, $2 \times 2 \times 2$ completely randomized factorial ANOVA was

Table 5.5 Participants structure divided by personality traits, type of recipients and topics chosen by them at the time of their recruitment.

	High neuroticism		Low neuroticism	
Topics	Family	Friend	Family	Friend
Health	26 (14 males)	31 (19 males)	47 (21 males)	47 (21 males)
Finance	29 (10 males)	28 (10 males)	42 (23 males)	40 (22 males)
Isolation	38 (18 males)	37 (22 males)	37 (19 males)	39 (19 males)
Reasons to live	45 (23 males)	40 (19 males)	32 (16 males)	31 (16 males)
Total (N = 589)	138 (65 males)	136 (70 males)	158 (79 males)	157 (78 males)

performed on each messaging option, with the factors of recipient type, discloser's gender, and the neuroticism traits of the participants in each of four topics.

5.4 Results

5.4.1 Scale Validity

EFA using the maximum likelihood method with a promax rotation was performed for all 15 items. The factor analysis revealed three factors with eigenvalues greater than one, and the scree plot indicated a clear leveling-off point after the third factor (Fig. 5.3). In addition, these three factors accounted for 44.7% of the overall variance. Table 5.6 listed factor loading of each item loaded onto the three factors (factor loading > .40), and any cross loading items are not found[10].

The first factor was labeled *Support request type*. This factor consisted of five items; e.g., "(Q4) I want the robot to ask the recipient to help me with my trouble" and "(Q11) I want the robot to report the message in a way that the robot itself is worried about my trouble" (Cronbach's α = .79).

The items loaded onto the second factor related to behaviors of the robot that conceal the some part of the self-disclosed contents, and we labeled this factor *Conceal type*. This factor consisted of five items; e.g, "(Q2) I want the robot to tell this story to him/her as common trouble of elderly people" and "(Q3) I want the robot to tell him/her without saying my true emotions" (Cronbach's α = .74).

Factor 3 items related to the message formats that contains more non-verbal information of the elderly discloser than the case that the mediator robot reads out

[10]To obtain a simple structure, (Q7), (Q8) and (Q13) were removed whose factor loading were less than .40

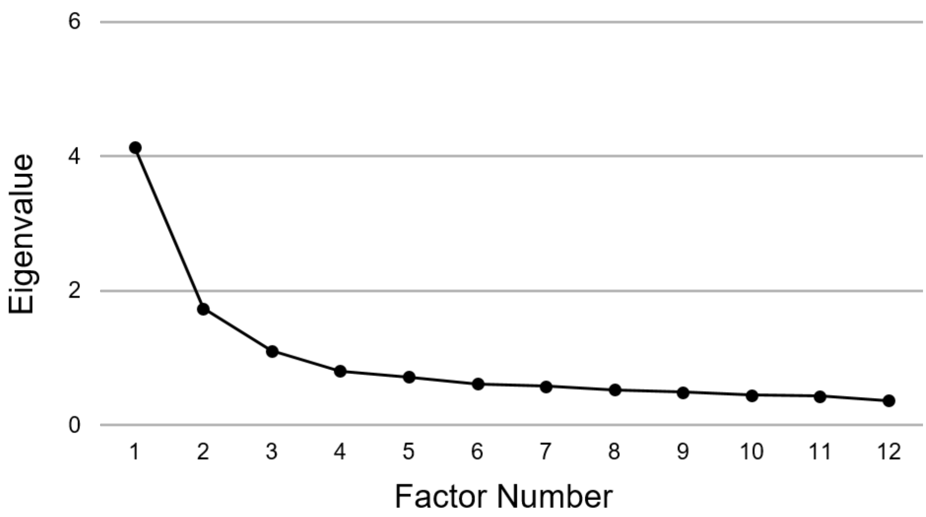

Fig. 5.3 Scree plot (main study)

the message by using its voice. This factor consisted of two items; "(Q14) I want the robot to tell him/her using my recorded voice" and "(Q15) I want the robot to tell him/her using my recorded movie." Thus we labeled this factor *Record type* (Cronbach's α = .69).

In addition to the all of the those factors had relatively high or moderate levels of the scale reliability, the items which comprised each factor were semantically consistent with each other. We conclude that these items can be used as a valid scale to measure the preference for messaging options.

5.4.2 Filtering the Minor Options

Table 5.6 shows chi-square values of each comparison in the number of participants who scored more than 4.0 and those who less than 4.0. In *support request type*, the number of participants who preferred (Q9) and (Q11) were greater than those of who did not. Therefore, these items could be regarded as *major options*. As there is no significant differences in the number of participants who preferred and who did not preferred (Q14) and (Q15), these items were regarded as *detail options*. Additionally, the number of the participants who did not prefer (Q6) was larger than who preferred this item, thus the messaging option can be classified into *minor options*.

For (Q10) and (Q11) in the *conceal type*, there was no significant difference in the number of the participants. Thus, these items could be regarded as *detail options*. Since, the number of the participants who rated over 4.0 on (Q4), (Q6), and (Q13)

Table 5.6 Factor loading and chi-square values from comparisons in the number of participants

Category of messaging option	Variable	Factor loading I	II	III	Num. of participants scored > 4	scored < 4	χ^2 $df = 1$
Support request type	Q4	**.743**	-.051	.020	188	191	.24
	Q11	**.728**	-.027	-.072	**279*****	148	40.2
	Q9	**.620**	-.238	.041	**354*****	73	185
	Q6	**.582**	.031	.146	153	**257*****	26.3
	Q5	**.572**	.198	-.021	187	184	.024
Conceal type	Q2	.127	**.697**	-.057	208	188	1.01
	Q3	-.216	**.683**	.010	160	**215*****	8.07
	Q1	.158	**.646**	-.129	189	223	2.81
	Q12	-.047	**.595**	-.103	122	**243*****	40.1
	Q10	-.126	**.432**	.174	99	**303*****	104
Record type	Q14	-.001	.036	**.783**	190	206	.65
	Q15	.151	.040	**.570**	142	**252*****	30.7
Eigenvalue		4.14	1.74	1.11			
Variable explained		30.15%	9.69%	4.89%			

*** $p < .001$

were significantly smaller than those who rated less than 4.0, these items were classified as *minor options*.

For (Q14) in the third factor it record type, as there was no significant difference between the number of the participants, this item was classified into *detail options*. The number of participants who preferred (Q15) was significantly smaller than those of who did not prefer the item, thus the messaging option can be classified into *minor options*.

5.4.3 Differences in Preferences by the Situation

We analyzed how the preference for messaging options classified into *detail options* were varied according to the situation. Significant ($p < .05$) and marginal ($p < .06$) results (main effects and interactions) obtained through ANOVA described in section 5.3.5 are summarized in Table 5.7.

Health Topic

In a topic concerning *health*, only messaging options belong to *support request type* showed significant effects. A significant main effect of the discloser's neuroticism was found at (Q4). Participants having higher neuroticism (HN) traits preferred the

Table 5.7 Significant and marginal results for preference of each messaging option classified into the detail options. 2×2×2 ANOVA was performed on each messaging option, with the factors of recipient type, discloser's gender, and the neuroticism traits of the participants in each of four topics (SR type, C type, R type denote *support request type*, *conceal type*, and *record type*, respectively).

Topics	Detail Options		Significant factor	f	p	η^2
Health	SR type	(Q4)	neuroticism	$f(1,143) = 4.04$	.046	.027
		(Q5)	gender × recipients	$f(1,143) = 3.69$	.057	.025
Finance	SR type	(Q4)	gender × recipients	$f(1,131) = 5.76$	.018	.042
	C type	(Q1)	gender × recipients	$f(1,131) = 3.68$	.057	.027
		(Q2)	gender × recipients	$f(1,131) = 4.00$	.048	.03
	R type	(Q14)	gender × recipients	$f(1,131) = 3.99$	.048	.03
Isolation	C type	(Q1)	recipient × neuroticism	$f(1,143) = 3.99$	.048	.027
	R type	(Q14)	gender × neuroticism	$f(1,143) = 6.13$	.014	.041
Reasons to live	C type	(Q1)	recipient × neuroticism	$f(1,140) = 3.96$	.049	.027
		(Q2)	gender	$f(1,140) = 3.99$	.048	.028
			recipient × neuroticism	$f(1,140) = 6.55$	.012	.045

(Q4) item more than those with lower neuroticism (LN) ($M_{HN} = 4.14$, $M_{LN} = 3.67$). Also, in this topic, a marginal interaction between the discloser's gender and the recipient type was found at (Q5). Female participants agreed to use this messaging option on their friend rather than their family members ($t = 2.27$, $p = .025$, $df = 143$). In addition, when family members were assumed to be the recipients of the message, female participants preferred the (Q5) item less than male participants ($t = 2.20$, $p = .030$, $df = 143$) (Figure 5.4 left).

Financial Topic

In a topic concerning *finance*, significant/marginal interactions between the discloser's gender and the recipient type were found in every types of messaging option.

Regarding *support request type,* (Q4) showed a significant effects in which female participants agreed to use this messaging option on their family members than their friends ($t = 2.05$, $p = .042$, $df = 131$). In addition, when friends were assumed to be the recipients of the message, female participants preferred the (Q4) item less than male participants ($t = 1.93$, $p = .056$, $df = 131$; Figure 5.4 right).

For (Q1) and (Q2) which belong to *conceal type,* showed the similar tendencies in which the male participants agreed to use these messaging options on their friends

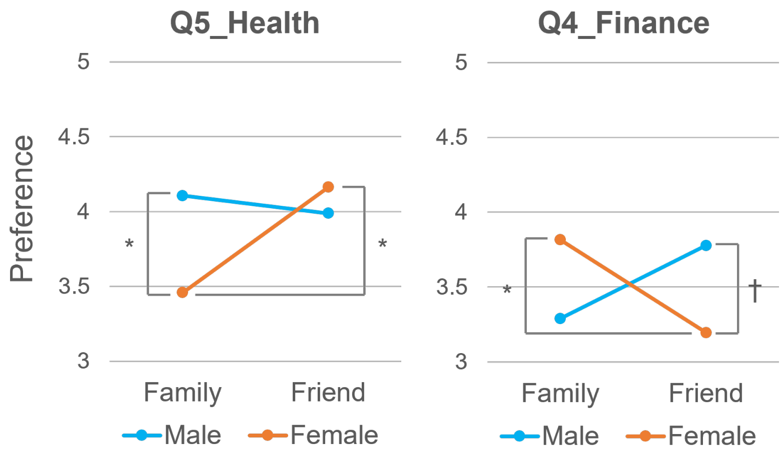

Fig. 5.4 Preference for Q4 and Q5 which were classified into support request type. Significant interactions were found in the topics concerning health and finance.

than their family members ((Q1) $t = 1.79$, $p = .076$, $df = 131$; (Q2) $t = 2.30$, $p = .023$, $df = 131$; Figure 5.5 left).

For (Q14) included in *record type*, there was a gender difference particularly in case that friend recipients were assumed: female participants preferred the (Q14) item less than male participants ($t = 2.72$, $p = .008$, $df = 131$; Figure 5.6 left).

Topic Concerning Isolation

In a topic concerning *isolation*, a significant interaction between the recipient type and the discloser's neuroticism was found at (Q1) which belongs to *conceal type*. Post-hoc comparison showed that participants with higher neuroticism preferred to use the messaging option on their friend than their family members ($t = 1.71$, $p = .089$, $df = 143$; Figure 5.5 center).

Furthermore, an another significant interaction was observed at *record type*, which involves the factors of the discloser's gender and the discloser's neuroticism. More specifically, male participants with lower neuroticism preferred the (Q14) item than those who with higher neuroticism ($t = 2.36$, $p = .019$, $df = 143$). Also, a significant gender difference was found in the participants group with lower neuroticism; male participants preferred the (Q14) items than female participants ($t = 2.75$, $p = .007$, $df = 143$; Figure 5.6 right).

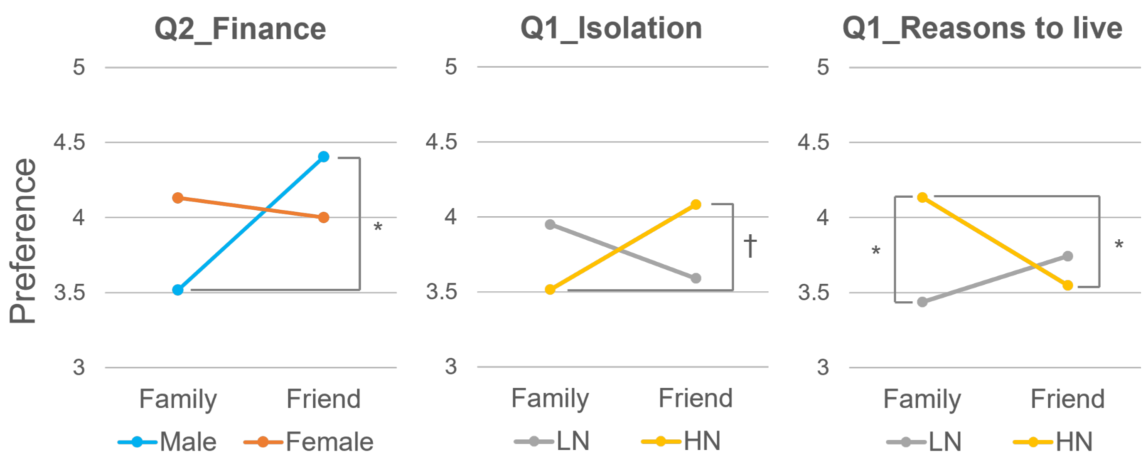

Fig. 5.5 Preference for Q1 and Q2 which were classified into conceal type. Significant interactions were found in the topics concerning finance, isolation, and reasons to live.

Topic Concerning Reasons to Live

In this topic, the significant results were found only in the *conceal type*. A significant main effect of the discloser's gender was found at (Q2): male participants preferred the messaging option more than female participants (M_{male} = 4.05, M_{female} = 3.61). Also, significant interactions between the recipient type and the discloser's neuroticism were found both at (Q1) and (Q2), which indicate participants with higher neuroticism agreed to use these messaging options on their family members than their friends ((Q1) t = 2.00, p = .047, df = 140; (Q2) t = 2.00, p = .048, df = 140). In addition, when family members were assumed to be the recipients of the message, participants with higher neuroticism preferred to use these messaging options than those who with lower neuroticism ((Q1) t = 2.24, p = .023, df = 140; (Q2) t = 2.43, p = .016, df = 140; Figure 5.5 right).

5.5 Discussions and Limitations

EFA suggested that the robot may need to have three different categories of messaging options which were labeled *support request type*, *conceal type*, and *record type*. Also, another analysis identified that two messaging options (Q9 and Q11) which belong to *support request type* were preferred by the majority of the participants. This may imply that, when designing behaviors such as requesting support to the recipients, it maybe effective to add non-verbal expressions to the robot for conveying its (Q9)

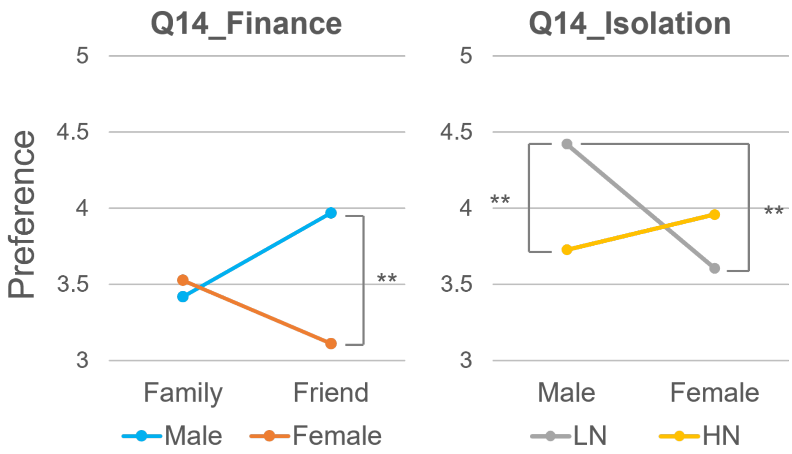

Fig. 5.6 Preference for Q14 which was classified into record type. Significant interactions were found in the topics concerning finance and isolation.

seriousness and (Q11) anxiousness. For example, it is known that the robot's internal weight movements can make it be recognized as serious, and the reactions of the message recipients are influenced by such the robot movements (introduced in Chapter 8). By applying such the novel expression modality to the mediator robot, the impact of the message reporting would be enhanced. Future work should include further exploration of the non-verbal aspects of the robot, especially when it reports messages to the recipients.

On the other hand, *detail options* were detected, and the preferences for these, as expected, turned out to vary depending on the situation. For example, in a topic concerning *finance*, male disclosers preferred to use the messaging options included in *conceal type* on their friends. This finding is consistence with the implication obtained in the preliminary survey, which the male disclosers tend to feel strong anxiety when they talk about their financial issue to their friends. Thus, the example suggests that messaging options may be chosen by the elderly users for avoiding their negative feelings perceived in self-disclosure.

However, the obtained results were based on the online survey. To know the effectiveness of the messaging options designed in this study, a verification in physical HRI experiment is needed, particularly focusing on the effects on human anxiety. Therefore, in the next chapter, we investigate whether the function of the robot that allows the elderly users to choose the messaging options can reduce their anxiety in self-disclosure.

Chapter 6

How Should Social Mediator Robot Deliver Messages of the Elderly?: An Empirical HRI Study

According to the self-presentation theory of social anxiety [84] (introduced in Chapter 5), if we know how to make a good impression on others, our anxiety will be reduced. If so, if the mediator robot provides multiple messaging options and allows the elderly discloser to choose the one that best suits his or her preferences, the discloser's anxiety may be suppressed.

In this study, an HRI study was carried out to test the hypothesis above. More specifically, elderly participants (N = 36) were asked to interact with either of the following two mediator robots, assuming a situation in which they self-disclose their *loss experience* to their own family members who are living in remote place.

- **Mediator robot 1**: when reporting the message, it just repeats the original message contents what the discloser input, by using its voice (conventional mediator robot).
- **Mediator robot 2**: when reporting the message, it applies preferable messaging option that the elderly discloser chose. The messaging options developed in Chapter 5 were implemented on this mediator robot.

However, human factors such as fear of negative evaluation (FNE) [168] influences the anxiety of human disclosers. People with a stronger FNE are likely to be more nervous than those who with lower FNE particularly when they do not know how to provide their good impressions to others [84]. Therefore, when analyzing the effects of the robot behaviors, hierarchical linear regression analysis was applied for controlling human factors such as:

- Anxiety in anticipation of self-disclosure over the phone
- Fear of negative evaluation (one of the temperament factor of the discloser)
- Personality traits of the disclosers/recipients based on the Big Five
- The gender factor of discloser and recipients

6.1 Robot Implementation

6.1.1 Robot Platform

The platform used in this study is Type-2 robot introduced in Chapter 4, a table-top dialog robot specifically developed to study the elderly self-disclosure. It has 6 DOFs (3 DOFs on the neck; head nod, tilt, and swing, 2 DOFs on the arms; left and right, and 1 DOF for body rotation). For this study, a modification was provided to the actuators of the robot. More specifically, an actuator in each joint was replaced to Kondo KRS-3302 ICS servo motor from SG92R hobby servo motors to achieve smoother and silent body movements. These servo motors are controlled by Arduino microcontroller which is connected to a laptop with Python scripts running. The other hardware specifications are the same as described in Chapter 4.

6.1.2 Dialog System

A Python script is run at the laptop which is connected to the robot to provide dialog interactions. For implementation, we used the Google speech-to-text API for speech recognition. For speech synthesis, a text-to-speech API (VoiceText Web API) provided by HOYA was used. By combining these dialog functions with physical expressions (such as nodding), the robot could provide audiovisual feedback in the human message creation process (in this study, a nodding expression was presented for each pause in the user's speech).

The interaction with the robot is initiated by a key phrase "send a message" which is inputted by the user. In response to the user's command, the robot provides the following utterance: "We will send a message to (RECIPIENT). Please tell me the message you want to send. When you finished the input, please say "input finalized".” Then, the user can input any message to the robot until he or she say "input finalized" which is also the key phrase for closing the message creation process. After the message input has been finished, the robot will try to interact with the user in two different ways as described in the next section.

Mediator Robot 1

Behavior of mediator robot 1 is designed so as to be similar to the one which the conventional mediator robots have. The robot repeats to the message recipient exactly what the discloser has input to it. When the user finalized the input of the message, the robot makes the following speech response: "I will close the message input. Then, I will tell (RECIPIENT) in this away. (DISCLOSER) said (MESSAGE)." As described in Chapter 5, the part written as (DISCLOSER) and (RECIPIENT) are replaced by the name of the elderly discloser and the message recipient, respectively. In the experiment, the experimenter asked each participant the names to be replaced by, and they were used in the robot speech. In addition, the part written as (MESSAGE) is replaced by the elderly's original message which is listened by the robot.

Mediator Robot 2

Messaging options developed in Chapter 5 have been implemented to mediator robot 2. More specifically, five messaging options classified as detail options in the analysis performed in Section 5.4.2 were used. In addition to those, the conventional behavior of the mediator robot (just repeating to the recipients) was also implemented. In summary, mediator robot 2 has a total of six messaging options shown in Table 6.1. Each of the elderly user can select the messaging option that is preferred for him/her followed by the instructions of the robot such as: "How should I convey this message to (RECIPIENT)? Please tell it me at the number." When selecting a messaging option, a tag number representing each messaging option was presented.

6.2 Method

6.2.1 Participants

Participants for this study were recruited through the people who are registered for municipal employment service centers for older people in Tokyo, Japan. We obtained 36 participants over 65 years (19 males; 17 females; age: M = 72.9 years,

Table 6.1 Messaging options implemented on mediator robot 2. In the usage, each of the user tells the tag number to the robot after talking their message contents. More detailed descriptions on each messaging option are shown in Section 5.3.1.

Category of messaging option	Number tag	Behaviors in message reporting
Conventional option	1	Report the message as it is.
Support request type	2	Ask the recipient to help the trouble of the discloser, not just report the message.
	3	Tell the recipient that other elderly people are being helped by their family members and friends, not just report the message.
Conceal type	4	Report the message to the recipient as just a speculation of the robot while concealing that the user disclosed his/her troubles.
	5	Report the message to the recipient as a common trouble of elderly people while concealing that the user disclosed his/her troubles.
Record type	6	Report as a voice message.

SD = 3.84). The study was a between-participants design, and the participants were divided into two groups based on each robot condition (mediator robot 1: $N = 16$; mediator robot 2: $N = 20$). The target profiles of participants in the recruitment were: (1) persons who were communicating with their own children and intimate friends at least once in three years by phone or face to face; (2) persons who were living alone or with their spouses only; (3) persons who had own troubles regarding either of loss experience topics (health, financial, isolation, and reasons to live)[1]. In the recruitment process, each participant was also asked their agreement to disclose their troubles about these topics to the robot. Each participant was paid 5,000 JPY (~ 90 min) for their cooperation. The study protocol was approved by the Research Ethics Committee in the Faculty of Engineering, Information, and Systems in the University of Tsukuba (2015R109-5), and all participants provided informed consent. The fieldwork period was from October 18th to December 15th in 2021.

[1]Target profile of the participants were almost the same as the one in Chapter 4 and Chapter 5. However, by considering the difficulties of the recruitment for conducting a physical HRI study, a statement in (3) "(loss experience topics) that had never been disclosed to their family members or friends" was removed. In fact, although we initially recruited 40 participants, four of them stated that they had disclosed all their problems to their family members, thus they could not imagine a situation where they do self-disclosure again. Therefore, data obtained from those four participants were removed from the analysis.

6.2.2 Measurement

Anxiety

To measure the anxiety state of participants when they disclose their troubles, twenty question items included in State-Trait Anxiety Inventory (STAI) were used (e.g., I feel stress, I feel nervous, etc.)[2]. When asking, a 4-point Likert scale was used (in this study a Japanese version of STAI [54] was used).

Fear of Negative Evaluation

Fear of negative evaluation from other people has been considered to be closely related to the levels of social anxiety [84]. To measure this, Watson and Friend created the Fear of Negative Evaluation Scale (FNE) [168]. This is one of the most frequently used scale in the literature of social anxiety (e.g., [171]). In this study, a variant of FNE which is short and Japanese version was used [141]. It contains 12 questions items (e.g., I often worry that other people may notice my shortcomings, I am always concerned about what impression I am giving to other people, etc.). A 5-point Likert scale of "1: strongly disagree" to "5: strongly agree" was used in answering to the question items.

Big Five Personality Traits

Discloser's personality traits are the factors that may influence their perceptions of anxiety when making a self-disclosure [70, 130]. Thus, each of the participants was asked their self-report personality traits based on the ten items personality inventory (TIPI-J [120]). This scale contains two items to measure each personality trait in the Big Five personality model (extroversion, neuroticism, agreeableness, consciousness, openness). A seven-point scale of "1: strongly disagree" to "7: strongly agree" was used in answering to these question items. Furthermore, since the personality traits of the recipient person may also affect the anxiety perceived by the discloser, each participant was asked the personality trait of the recipient person based on this scale.

[2]STAI [151] measures two types of anxiety: state anxiety, which is anxiety about an event, and trait anxiety, which is the degree of anxiety as a characteristic of an individual. The question items used in this study were the ones for measuring the state anxiety.

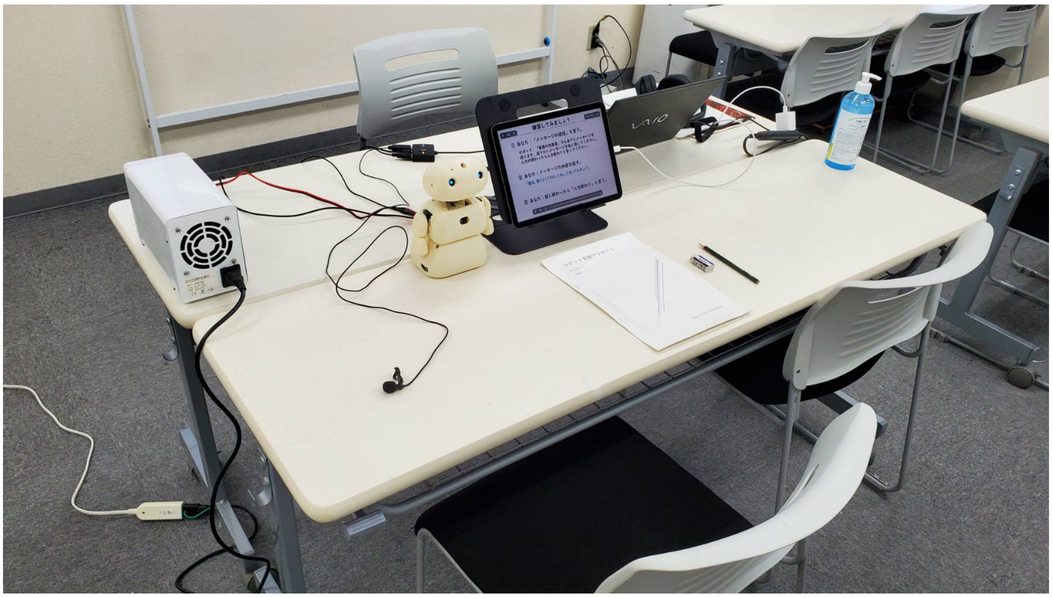

Fig. 6.1 Laboratory setup. Elderly participants sat in a chair in front of the robot. The experimenter sat in a chair behind the robot. An iPad next to the robot displayed the robot's dialogue script. Messaging options were also displayed if mediator robot 2 was used.

6.2.3 Procedure

The study conducted under face-to-face condition between an experimenter and each participant in the environment shown in Fig.6.1. First, the participants were handed a questionnaire by the experimenter, and after filling out the survey on their age and gender, they answered the questions on FNE and personality traits of themselves. Next, participants were asked to recall one of their family members in young generations who lives in remote place and communicates with them the most, as the recipient of the self-disclosure. Family recipients selected by the participants included daughters (63.9%), sons (25.0%), and sons' wives (11.1%). 39% of the family recipients were the same gender as the disclosers. They had an average age of 42.6 years (SD = 6.21). To have a better awareness of the recipients during the study, all participants were asked to complete forms with initials of the recipients. After that, the participants were asked to answer the questions regarding the personality traits of the recipient person.

After the recipients were defined, the participants were asked about their troubles to be disclosed. Each participant chose one of the topics of their *loss experiences* concerning *health*, *finance*, *isolation*, or *reasons to live* in which they had. In addition, they were also asked what impression they wanted to give to the recipients when disclosing their own troubles. More specifically, they were required to write on 1) How do you want to be perceived by the recipient? and 2) What kind of help do you expect from the recipient? These questions were designed to facilitate each participant's motivation for self-presentation.

Next, a specific scenario was given to the participants in which they disclose their own loss experiences to the recipient directly over the phone. The anxiety state of the participants, which will be perceived in such a situation was measured by using the questionnaire items of STAI.

Then, each participant was asked to watch videos to learn how the interaction with mediator robot is like (e.g., about how each message is sent via mediator robot or how it reports the message to the recipient). The experimenter also supplemented the instruction by using ppt slides to provide a better understanding to the participants. For the participants who assigned to the condition in which they interact with mediator robot 1, they were instructed that "this robot repeats to the family recipient exactly what you has input to it" and none of the other messaging options were not informed. On the other hand, all of the messaging options and details of flow for switching these options were informed to the participants who assigned to the condition using mediator robot 2. When introducing the robot, the experimenter told "this robot has 6 patterns of behaviors for reporting your message. You can choose the one that you like the most. This robot will report the message to the recipient according to your choice." In addition to giving such the instructions, each participant had an opportunity to practice the usage of the mediator robot[3].

After measuring the participants' anxiety immediately prior to making self-disclosure to the mediator robot, the interaction with the robot was carried on. While the participants were talking to the robot, the experimenter waited outside the room. The entire interaction procedure with the robot was recorded by a video camera set up behind the participant.

6.2.4 Statistical Analysis

To compare the effects of two mediator robots on anxiety perceived in self-disclosure, a hierarchical linear regression analysis was applied. This method is a special form of a multiple linear regression analysis in which more variable are added to the model

[3]When practicing the interaction with the mediator robots, participants were asked to input "it's getting cold recently" as example of the message. Also, in this opportunity, participants who interacted with mediator robot 2 were asked to choose the messaging option "1" in which the robot reports the message as it is.

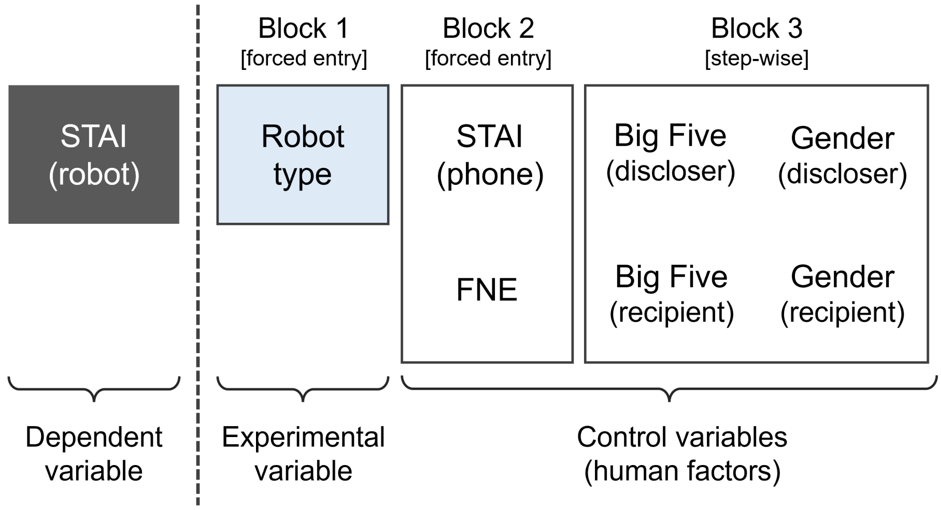

Fig. 6.2 Configuration of the hierarchical linear regression analysis applied in this study. Each variable was entered into the regression model along with the other variables in the corresponding block.

in separate steps called "blocks." This is often done to statistically control for certain variables [138]. The model was attempted to build via three blocks, summarized in Fig. 6.2. In the first block, a variable representing the type of robot was added. In the regression model building, this variable was entered by the forced entry method. In the second block, two control variables which expected to have strong effects on the dependent variable were included: a variable on anxiety in anticipation of self-disclosure over the phone and FNE. These variables were entered into the model by the forced entry method. In the third block, several explanatory variables were added via the step-wise method. Variables included in this block were the personality traits of both participants and recipients, and the gender factor of both participants and recipients.

6.3 Results

The results are summarized in table 6.2. As expected, certain human factors had significant effects on the perceived anxiety in self-disclosure to mediator robots. In particular, perceived anxiety in anticipation of self-disclosure over the phone and individual characteristics on fear of negative evaluation had significant positive coefficients in every regression models. The larger these values were, the greater the anxiety felt in self-disclosure to the mediator robots. In addition, significant regression coefficients on the personality traits of the discloser were obtained for

Table 6.2 Significant factors that influenced the anxiety of participants when they self-disclosed to mediator robots. A hierarchical linear regression analysis showed that the robot type had a significant effect in model 4 and model 5. In this analysis certain human factors were statistically controlled. The table present standardized regression coefficients (B) and standard errors (SE) for each measure.

	Model 1		Model 2		Model 3		Model 4		Model 5	
Measure	B	SE	B	SE	B	SE	B	SE	B	SE
Intercept	4.10***	.28	-.25	.55	1.22	.82	2.08	.86	1.67	.83
Robot type	.079	.37	-.26	.22	-.33	.21	**-.49***	.21	**-.46***	.20
STAI (phone)			.53***	.19	.48***	.18	.56***	.18	.38***	.18
FNE			.78**	.12	.78*	.11	.80**	.11	.84*	.10
Big Five (discloser)										
Agreeableness					-.25*	.11	-.26*	.10	-.27**	.096
Openness							-.21*	.094	-.20*	.089
Neuroticism									.19*	.087
F-test value	.045		23.8***		21.7***		20.6***		20.1***	
Adjusted R2	-.28		.66		.70		.74		.77	

$* p < .05; ** \ p < .01; *** p < .001$

model 3, model 4, and model 5. Specifically, negative coefficients were observed for agreeableness and openness, and positive coefficients were observed for neuroticism. By statistically controlling for the influence of these human factors, we observed significant regression coefficients for robot type (in model 4 and model 5). This result suggests that participants who used mediator robot 2 reported less anxiety than those who used mediator robot 1 (model 4: $t = -2.36$, $p = 0.25$; model 5: $t = -2.36$, $p = 0.26$). On the other hand, none of the other variables (e.g., personality traits of the recipients and gender factors of the disclosers/recipients) had significant coefficients.

6.4 Discussions and Limitations

A mediator robot that reports messages to family members in a way that is preferable to the elderly users was shown to have the potential to suppress their anxiety about self-disclosure on loss experiences. Therefore, this study successfully provide an empirical evidence that the reporting behavior of mediator robots can potentially suppress discloser's anxiety about self-disclosure. Moreover, by conducting a physical HRI study, this results also successfully demonstrated the effectiveness of the messaging options developed in Chapter 5.

On the other hand, these effects were subtle and could only be observed after controlling for the effects of several human factors. For example, participants who reported strong anxiety if they were to self-disclose directly to the recipient over a phone, also perceived strong anxiety when using a mediator robot. In addition, the discloser's temperamental characteristics regarding FNE and neuroticism trait were also factors that contributed to the anxiety of the elderly participants. On the contrary, the discloser's agreeableness and openness traits were factors that suppress the anxiety about self-disclosure to the robot. Meanwhile, agreeableness and openness traits have been shown weak relationships with social anxiety in a psychological study [70], thus the positive regression coefficients observed in our models may represent individual differences in affinity for robots. Agreeableness reflects the extent to which someone is cooperative and friendly [121]. Although there are not many literature reported the effects of this human trait in HRI, Bernotat and Eyssel found that high agreeableness predicted a positive evaluation of the interaction with an intelligent robotics apartment while the other traits (i.e., openness, extroversion, conscientiousness, and neuroticism) did not predict it [13]. Similar to them, our study results may also be suggesting that the elderly participants who had higher agreeableness were more receptive to the robot and did not feel high anxiety. Regarding the openness trait, it represents the degree to which someone is imaginative, curious, and broadminded [131]. This may suggest that the elderly participants with higher openness were more willing to interact with our robots without feeling anxiety.

However, in this study, more complicated human factors, such as the interaction among multiple factors was not considered. There may be other human factors that influence human anxiety, and these structures might also be complex.

Also, our experiment aimed to verify the impact of the different behaviors of the robot, and all measurements were conducted in a relatively short time window. However, long term trust development may be a key element for the use of mediator robot. Further exploration is needed to pursue this aspect of mediator robots.

Another limitation is that the participants in this study were relatively healthy and active people who regularly communicate with their family members (at least once in three years). Although it is quite difficult to recruit only a certain number of truly isolated elderly people, empirical studies among them are also important.

Lastly, the results obtained from this study may not be supported when using robots with different specifications (e.g., its appearance and/or vocal features). Future work is needed to test our interaction model in other robot platform such as the one having more human-like appearance.

Chapter 7

Enhancing the Non-Verbal Expression Capabilities of Social Mediator Robot Through Internal Weigh Movements

In this chapter, a robotic gadget that is equipped with a movable weight inside its body is introduced. By controlling the movement of the internal weight together with other robotic behaviors such as hand gestures or speech dialogues, it is expected that emotional and/or intentional messaging between users is enhanced (Fig.7.1). After introducing the related works about weight shifting technologies and haptic interactions in social robots, the hardware specification of OMOY will be presented. In addition, this chapter reports an elicitation study conducted to investigate how users holding this gadget in their hand interpreted its 36 weight shift patterns generated by setting four basic movement parameters (target position, trajectory, speed, and repetition). The contents of this chapter are based on the following publication:

- [110] Yohei Noguchi and Fumihide Tanaka. OMOY: A Handheld Robotic Gadget That Shifts Its Weight to Express Emotions and Intentions. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems. ACM, 2020. paper 646.

7.1 Related Works

Vibrotactile (touch and vibration) stimuli have been used for communication purposes since Geldard first discussed this topic in the 1950s [42]. A three-fingered

Fig. 7.1 The robotic gadget, named OMOY, developed in this study can exhibit various *weight shifts* to express emotions and intentions. A movable weight is implemented inside its body and is controlled by the translational and rotational mechanisms determined by four parameters (target position, trajectory, speed, and repetition). By exhibiting appropriate weight shifts together with gestures or speech dialogues, emotional and intentional messaging between users is expected to be enhanced.

tactual display called Tactuator was an early device that was able to transmit complex information through vibrotactile stimuli [157]. Recently, ComTouch expanded this concept to remote interpersonal communication using mobile phones [21]. Réhman studied in detail the use of vibrotactile rendering in mobile phones [126]. Vibration motors were used to render vibrotactile patterns that expressed human emotions [127, 128]. Similar methods have also been applied for the emotional expressions of game avatars [8]. All of these works used vibrotactile stimuli generated by vibration motors. By contrast, the present study explores stimuli caused by weight shifts implemented by the combination of two (translational/rotational) motions of a weight. In this chapter, we will report the study results that are characteristic of such weight shifts.

Handheld devices equipped with weight shift functions have been explored in VR (virtual reality) or game applications. TorqueBAR [155] is an ungrounded force feedback device having a weight moving horizontally (1D) between left and right. Possible applications for the device such as video games and navigation were discussed based on a user study [155]. Weight-Shifting Mobile [53] is a mass-shift based system for haptic actuation in mobile phones. It was tested whether users were able to determine the position of a weight inside the device [53]. To change both the weight and volume of a device, liquid metal transfer by using a bi-directional pump was proposed [107]. This method was able to be applied for making a miniature solar system and motion control [107]. Shifty [175] is a rod-shaped VR controller that can change its internal weight distribution to enhance object perception. It also has a weight moving in 1D to enhance the user perception of virtual objects changing in shape (length). Transcalibur [145] is a transformable VR controller that can render a 2D shape by changing its mass properties on a 2D planar area. A computational model to control the movement of the controller was obtained from a user study [146]. Compare to these previous works, the novelty part of the present study exists in targeting emotional and intentional messaging between a device and its user by introducing more complex weight shift patterns in 2D space than these previous works.

Emotional expression is a major research topic in robotics. Facial expressions have been most commonly explored since the 1990s [49]. SEER, which was recently demonstrated at SIGGRAPH 2018 Emerging Technologies, has state-of-the-art capability in its facial expressions [162]. The whole body movement [101], sounds [64], colors [159], vibration motors [149], and their combinations [89, 149] have also been used for expressing robotic emotions. In addition, haptic factors such as skin temperature [106, 122, 14], skin texture [62], and SwarmHaptics [77] are discussed within the context of robotic emotional expression. However, the use of weight shifts was unexplored in social robotics.

7.2 Hardware Design

The overall hardware specifications of the robotic gadget, named OMOY, are illustrated in Figure 7.2. The dimensions of OMOY are approximately 240 mm (H) × 125/230 mm (arm closed/arm open) (W) × 95 mm (D), and its total weight is 720 g. To minimize the influence of prior knowledge or experience with other commercial robots, OMOY was designed with a simple appearance. Following the information

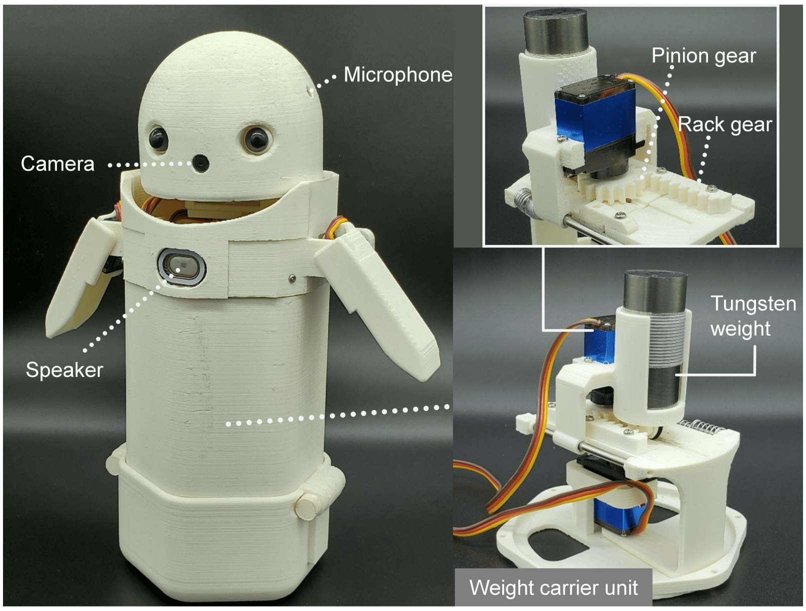

Fig. 7.2 Prototype of OMOY. A 250 g tungsten weight is attached to the weight carrier unit, which allows the weight to move along a 2D planar space. For translational motion, the mechanism was actuated by a servo motor through rack and pinion gears.

reported in [90], its facial appearance (eyes) was designed to render the robot suitable for home use. For prototyping, the eyes were represented as plastic glossy black buttons that are often used for stuffed animals. The mechanical designs of the *weight carrier unit* that controls the weight shifts and the *robotic unit* that controls the voice and other robotic behaviors will be explained in the following sections.

7.2.1 Weight Carrier Unit

The body exterior of OMOY forms a regular hexagon. The inside shapes cylindrical with a diameter of 80 mm. In that hollow space, 250 g of tungsten weight ($\phi 20 \times l 42$ mm) is implemented. Tungsten has a large specific weight (19.3 g/cm^3), high chemical stability, and a reasonable price.

When a user grips the gadget, two types of friction are applied to the skin surface: a frictional force against gravity and a frictional force that stops the rotation. Assuming that the user holds the robot at two points, the thumb and middle finger, and assuming that the static friction coefficient μ for the robot surface and human skin is uniform, the force F that the user should apply perpendicular to the robot to fix its position and posture is derived as below.

$$F = \frac{g}{2\mu}\left\{m\left(1+\frac{3}{D}l\right)+M\right\}. \tag{7.1}$$

(m: mass of the weight, M: mass of the gadget excluding the mass of the weight, l: inner radius of the gadget, D: diameter of the human-gadget contact area) In addition, according to Weber's law in psychophysics, the human differential threshold on the skin for pressure stimulus is 1 of 7 [105]. Based on these relationship, we simulated F for different parameters m, M, l, and D, and concluded that the weight should be 250 g or more for implementing the gadget. The tungsten weight is attached to a translational and rotational mechanism that allows the weight to move along a 2D planar space.

For the translational mechanism, rack and pinion gears were used, which were 3D-printed with ABS resin. The pinion gear is connected to a Tower Pro MG92B servo motor (3.1 kgf·cm output for a 5.0 V input) and conveys its torque to the rack gear. The total length of the rack is 47.6 mm, and the weight can be moved from the origin (center of the robot) to the inner wall of the robot for each gear pitch of 3.86 mm. The translational weight shifts are guided by two metal shafts (ϕ 6 mm) next to the servo, rack, and pinion gears (path of the weight), and coil springs are applied to these metal shafts for shock absorption. In addition, a wheel is attached under the weight to ensure that the movements are smooth. The total weight of the part assembly (including the tungsten weight, servo motor, pinion gear, wheel, and weight-servo joint) moved by the translational mechanism is 280 g.

For the rotational mechanism, the MG92B servo motor was used. This motor is not only vertically connected to the translational mechanism but is also fixed to the robot exterior through the base of the weight carrier unit. In this prototype, the weight is capable of rotating in any direction between 0 and 180 degrees on the front side of the robot.

7.2.2 Robotic Unit

OMOY has two DOFs on its neck (head nod and swing) and one DOF on each shoulder (right/left), and a Tower Pro SG92R servo motor is introduced to each joint (2.5 kgf·cm output for 5.0 V input). An Arduino Nano microcontroller board is used to control these servo motors and is serially connected via a USB to a small built-in CPU board (Raspberry Pi Zero). The CPU board is also connected to a microphone array (Seeed Studio ReSpeaker 2-Mics Pi HAT) and a camera module (Raspberry Pi Camera Module V2), both of which are embedded in the robot's head. The "ear holes" are located on both sides of the robot head, and the camera hole is located on the face. In addition, a micro speaker module is mounted on the chest.

We envision that OMOY will be used as a *social mediator* that connect humans by delivering messages. Thus, we implemented the capability for voice interactions by using a Google Assistant API. Messages can be exchanged through an HTTPS web server that was developed to manage messages posted and requested from the robots. A Python script runs on the built-in CPU board, which provides speech, web server access, and high-level robot control, and the Arduino Nano controlled the servo motors to provide weight shifts and other robotic behaviors. The power for the robot was supplied by 5 V DC via a micro USB and can also be supplied by mobile batteries often used for smartphones or smart devices. Thus, the robot can be operated in a portable manner.

7.3 Elicitation Study

To design the effective use of weight shifts, we need to know about the perception of users towards weight shift patterns. To obtain such knowledge, we conducted an elicitation study. A total of 36 weight shift patterns generated by setting four movement parameters (target position, trajectory, speed, and repetition) explained in below were exhibited to 18 participants. Each participant tested these 36 weight shift patterns one by one, and then was interviewed by an experimenter (Figure 7.3). Because we wanted to know first about the effects of weight shifts, in this study, we focused on the weight shifts, i.e., other behavioral functions such as head/arm movements or speech dialogues were not used.

Considering the future use case of OMOY as a social mediator that was mentioned in the previous section, it was required for OMOY to be able to convey the "importance" of a message. Following psychology literature [67] suggesting that the abstract concept of importance is grounded in bodily experiences of weight, we aimed to create weight shifts in which users could feel as if OMOY gained its weight when reporting important messages. During pilot trials repeated within researchers, we found that movements toward the front side were easier to perceive a weight gain than them toward the back side. It was presumably because the front side was more apart from users' hand (thus made them feel more weight by lever principle)

Fig. 7.3 Elicitation study: Each participant was exhibited 36 patterns of weight shifts by OMOY in his/her hand. An experimenter sat in front of the participant for the interviews.

than the back side. Therefore, we decided to explore weight shift patterns mainly in the front side area.

In determining movement parameters, we also referred to [77] in which a haptic interaction case involving small mobile robots having 2D-spacial and 1D-rotational degrees of freedom were discussed. More specifically, movement parameters such as trajectory, speed, and repetition were chosen by referring to the approach taken in [77]. Then, we repeated pilot trials again to finalize the attributes of these parameters so that we had a set of representative weight shifts.

7.3.1 Four Movement Parameters

Target position

The target position is the destination of a weight movement. We explored three target positions: *front*, *ua_side*, and *op_side*, as shown in Figure 7.4. The *front* indicates the front side of OMOY facing toward the user holding it from the back with his/her non-dominant hand (see Figure 7.3).[1] The *ua_side* (user arm side) indicates the side that is near to the forearm of the user who holds OMOY, whereas the *op_side* indicates the opposite side of the *ua_side*.

[1]All data were converted such that the relative positional relationship between OMOY and each participant's hand was constant across all participants (right-handed and left-handed).

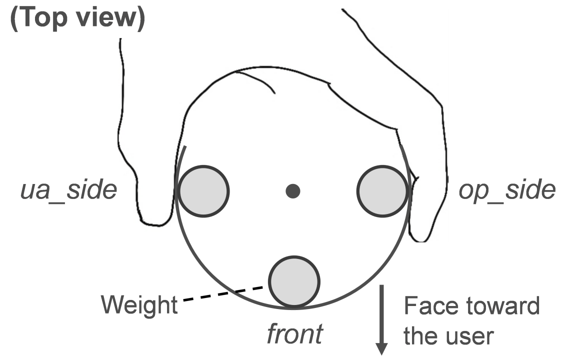

Fig. 7.4 Three target positions of the weight.

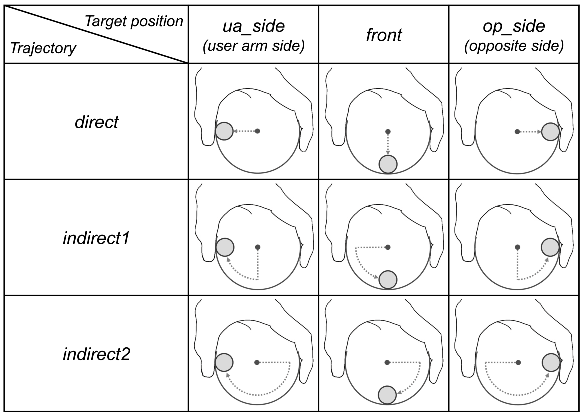

Fig. 7.5 Three target positions × three trajectories of the weight.

Trajectory

The shapes of the weight trajectories were manipulated in three ways shown in Figure 7.5: one *direct* path (traveling straight from the origin to a target position) and two *indirect* paths (traveling to a target position while passing through other positions). When the indirect paths are taken, a force is produced by the translations and a centrifugal force is produced by the rotations. After the target position is reached, the weight returns to the origin.

Speed

Two speeds were explored: *fast* and *slow*. Fast denotes the maximum speed at which the servo motor can move the weight, and slow denotes 30 % of the maximum speed. When the weight moves in the fast mode, the peak acceleration was observed as 6 m/s^2 for translation and 9 m/s^2 for rotation, as measured by a Kionix KXR94-2050 accelerometer. In the slow movements, acceleration peaks were observed at 2 m/s^2 for translation and 3 m/s^2 for rotation. The speed parameter was controlled by VarServoSpeed.h imported from Arduino library.

Repetition

Two types of repetition were explored: *single motion* and *repetitive motion*. For the single motion, the weight is moved only once to the target position while tracing a trajectory. In the repetitive motion, the weight performs one-and-a-half round trips along the trajectory as follows: 1) travel to the target position, 2) return to the origin through the same path, and 3) return again to the target position.[2]

7.3.2 Participants

Eighteen participants (14 males, 4 females, ages: 21–36 years) were recruited in the University of Tsukuba. None of the participants had mental disorder, arm/hand injury, or any other issues that could affect their performance during the experiments. Each participant was paid 1,660 JPY (~ 120 min) for their cooperation. The study protocol was approved by the Research Ethics Committee in the Faculty of Engineering, Information, and Systems in the University of Tsukuba (2019R317), and all participants provided informed consent.

7.3.3 Data Collection (Measurements)

For each weight shift pattern, we collected users' perceptions through interviews. Questions were presented through a questionnaire sheet and was orally answered by the participants.

Perceived haptic stimuli

We asked if the participants felt the weight moving inside the robot (prior to the trials, the participants had been informed that the robot would perform weight shifts inside its body, as will be described in the procedure section). Each participant

[2] In designing weight shifts patterns, two time delays were incorporated as follows. A 5.0 s pause was made at the end of each movement, i.e., between the time at which the weight lastly reached the target position and the time at which it began to return to the origin. A 0.3 s of transaction time was used for translation-rotation movements in the indirect path and for translation-translation and rotation-rotation movements in the repetitive motion.

answered either *"1: Yes, I felt."* or *"2: No, I didn't feel."* For this study, this question item was used to ensure that the participants could perceive each haptic stimulus.

Perceived emotional states

The perceived emotional state of OMOY during the weight shifts was evaluated. For this measurement, we used a nine-point Self-Assessment Manikin [15], which is a visual scale of three dimensions in the pleasure, arousal, and dominance (PAD) model [97]. The participants were asked to *"Please guess the emotional states of the robot."* and were presented with the manikin illustrations.

Perceived intentions

It is expected that participants perceive not only the emotional states but also the intentions of OMOY exhibiting weight shifts. Thus, we collected user descriptions of the OMOY's intentions during weight shifts by using an elicitation interview technique. To this end, we first asked the participants whether they perceived any intentions from the weight shifts of the robot. In the field of interaction between the human and computer agents, the intentions of agents are discussed in three dimensions: purposefulness, interaction, and animateness [31]. Following this concept, we revised a questionnaire item for measuring the purposefulness dimension and asked the participant *"How strongly was OMOY trying to express something to you?"* Each participant answered the question over a range of *"1: Not at all."* to *"9: Very strongly."* Then, the elicitation process was carried out in accordance with the score from the prior question. For the participants who perceived intentions (who marked a value 6 or greater on the previous question), we asked *"What words would you use to describe what the robot is trying to express to you?"* For the other participants (who marked a value of less than 6 on the previous question), we asked *"What words would you use to describe how it felt on your hand, if at all?"* Furthermore, the following questions were asked to all the participants: *"Was there anything else you felt or thought or are there any sensations or pictures that come in your minds?"* and *"Is there any additional comment related with this trial?"* These question items were based on the explicitation interview technique reported in [115].

7.3.4 Procedure

The trials were conducted under face-to-face conditions between an experimenter and each of the participants. Initially, each participant was given an overall introduction of this study, and their consent was requested, followed by instructions on how to interact with OMOY. It was introduced to the participants as *"a hand-held communication robot that is equipped with a movable weight inside the body,"* and we informed them that they would receive various haptic stimuli caused by the weight shifts. The participants were also instructed that in this trial OMOY did not speak nor move its hands, thus they paid attention to the weight shifts. In addition, they were instructed to hold OMOY from the back with his/her non-dominant hand (similar to the position for holding a smartphone) and not to tilt OMOY by more than 45 degrees (to prevent it from lying down). We disclosed all question items used in the interview process in advance, and then, 36 weight shift patterns were presented in a random order. The experimenter produced each stimulus by sending commands to OMOY through a laptop. Each pattern had a duration of less than 10 s and was presented twice. If the participant was ambivalent regarding his/her answer, we presented as many additional stimuli as the participant desired. At the end of each stimulus, the experimenter interviewed the participant regarding their perceptions of OMOY, with instructions to leave it on a table.[3] We held a break with a duration of a few minutes every 30 min, and all procedures were completed within 120 minutes. All of the experimental procedures, including each trial and interview, were videotaped.

7.4 Results and Discussion

7.4.1 Perceived Haptic Stimuli (Manipulation Check)

We checked whether each stimulus was well-perceived by the participants. For 28 of the 36 patterns, all participants reported that the weight was moving. For 5 patterns, 1 participant did not recognize the stimulus, and 2 participants for 1 pattern and 3 participants for 2 patterns reported that they did not feel the weight shifts. The conditions in which 2 or 3 participants did not perceive the stimuli were *front-indirect2-fast-single*, *op_side-direct-slow-single*, and *ua_side-direct-slow-single*, denoting [target position]-[trajectory]-[speed]-[repetition]. In the subsequent analyses, the data of participants who did not perceive the stimulus were excluded (in corresponding conditions).

[3]Participants were also informed that the weight shifting would stop for 5.0 s when each stimulus was completed. The participants were asked to answer the questions based on their feelings during continuous weight moving, excluding this long pause.

Table 7.1 Parameter results on perceived emotional states and intentions. The combinations of parameters having statistical significance are listed. 'Traj,' 'spd,' and 'rept' denote trajectory, speed, and repetition.

Pleasure				
front	spd	$F(1,193) = 12.2$	$p = .001$	$\eta_p^2 = .059$
	traj×spd×rept	$F(2,193) = 3.58$	$p = .030$	$\eta_p^2 = .036$
Arousal				
front	traj	$F(2,193) = 28.9$	$p < .001$	$\eta_p^2 = .23$
	rept	$F(1,193) = 11.0$	$p = .001$	$\eta_p^2 = .054$
	traj×rept	$F(2,193) = 5.32$	$p = .006$	$\eta_p^2 = .052$
ua_side	traj	$F(2,184) = 18.9$	$p < .001$	$\eta_p^2 = .17$
	spd	$F(1,184) = 34.8$	$p < .001$	$\eta_p^2 = .16$
	rept	$F(1,184) = 29.1$	$p < .001$	$\eta_p^2 = .14$
op_side	traj	$F(2,191) = 6.77$	$p = .001$	$\eta_p^2 = .066$
	spd	$F(1,191) = 24.3$	$p < .001$	$\eta_p^2 = .11$
	rept	$F(1,191) = 24.5$	$p < .001$	$\eta_p^2 = .11$
	traj×rept	$F(2,191) = 3.34$	$p = .038$	$\eta_p^2 = .034$
	spd×rept	$F(1,191) = 5.58$	$p = .019$	$\eta_p^2 = .028$
Dominance				
front	traj	$F(2,193) = 21.1$	$p < .001$	$\eta_p^2 = .18$
	rept	$F(1,193) = 5.92$	$p = .016$	$\eta_p^2 = .030$
	traj×spd	$F(2,193) = 4.51$	$p = .012$	$\eta_p^2 = .045$
ua_side	traj	$F(2,184) = 3.46$	$p = .033$	$\eta_p^2 = .036$
	spd	$F(1,184) = 5.15$	$p = .024$	$\eta_p^2 = .027$
op_side	traj	$F(2,191) = 4.13$	$p = .018$	$\eta_p^2 = .041$
	spd	$F(1,191) = 15.8$	$p < .001$	$\eta_p^2 = .076$
	rept	$F(1,191) = 4.89$	$p = .028$	$\eta_p^2 = .025$
Intentions				
front	rept	$F(1,193) = 6.37$	$p = .012$	$\eta_p^2 = .032$
ua_side	traj	$F(2,184) = 4.16$	$p = .017$	$\eta_p^2 = .043$
	rept	$F(1,184) = 6.06$	$p = .015$	$\eta_p^2 = .032$
op_side	traj	$F(2,191) = 4.60$	$p = .011$	$\eta_p^2 = .046$
	rept	$F(1,191) = 19.5$	$p < .001$	$\eta_p^2 = .093$

7.4.2 Parameter Results

We tested the effects of each parameter on the perceptions of emotional states (pleasure, arousal, and dominance) and intentions (purposefulness). Because the shapes of the trajectory depend on the target positions, $3 \times 2 \times 2$ ANOVA was performed for each target position, with the factors of trajectory, repetition, and speed.[4] All significant results are summarized in Table 7.1. Other detailed statistical results such as the mean values and standard deviations for each condition are provided in Appendix A.

[4]Repeated-measure metrics were not suitable for this analysis because missing data were removed through the manipulation check, with no answers from the participants.

Pleasure

For the target position *front*, a significant main effect of speed was observed; participants perceived more pleasure from the robot with *fast* weight shifts than for *slow* weight shifts.

For the three-way interaction confirmed with this target position, we performed a simple interaction test as a post-hoc comparison. The results indicated that the perceived pleasure for *front-direct-fast-repetitive* was higher than that for *front-direct-slow-repetitive* ($p = .007$). Moreover, the perceived pleasure for *front-indirect1-fast-repetitive* was higher than that for *front-indirect1-slow-repetitive* ($p = .007$). No significant effects were found for the other two target positions.

Arousal

A significant main effect of the trajectory for each target position was observed. Post-hoc comparisons using the Tukey HSD indicated that for the direct path to each target position, the perceived arousal was significantly lower than the two indirect paths (all $p < .05$).

A significant main effect of repetition was also observed for each target position: when the weight moved in a repetitive motion, OMOY was perceived as having a higher arousal state than when the weight moved in a single motion.

In addition, the effects of speed were significant with two target positions *ua_side* and *op_side*: the faster the weight moved, the higher the arousal state perceived as the weight moved to these target positions.

For the target positions *front* and *op_side*, an interaction between the trajectory and repetition was observed. A post-hoc comparison indicated that for the indirect paths, arousal was strongly perceived when the weight repetitively moved compared with a single movement: *front-indirect1* $t(193) = 2.84$, $p = .005$, $d = .66$; *front-indirect2* $t(193) = 3.56$, $p < .001$, $d = 1.07$; *op_side-indirect1* $t(191) = 2.29$, $p = .023$, $d = .48$; and *op_side-indirect2* $t(191) = 5.01$, $p < .001$, $d = 1.14$.

For the target position *op_side*, an interaction between the speed and repetition was observed. A post-hoc comparison indicated that the fast repetitive weight shifts were associated with higher arousal states than the slow repetitive ($t(191) = 4.24$, $p < .001$, $d = .92$) and fast single ($t(191) = 4.28$, $p < .001$, $d = 1.02$) weight shifts.

Dominance

A significant main effect of the trajectory for each target position was observed. Post-hoc comparisons using the Tukey HSD indicated that for the direct path to the *front* position, a lower dominance was perceived compared with the two indirect paths (all $p < .001$). In addition, when the weight moved to the *ua_side* position while passing the *op_side* position (*ua_side-indirect2*), a higher dominance was perceived compared with the direct path ($p = .035$). When the weight moved to the *op_side* position by passing the *ua_side* position (*op_side-indirect2*), the participants perceived a higher dominance compared with the other two paths (*direct* $p = .050$, *op_side-indirect1* $p = .025$).

The effect of speed was also significant for *ua_side* and *op_side* positions; the faster the weight moved, the higher the perceived dominance was.

In addition, the repetition was significant for two target positions *front* and *op_side*; a higher dominance was perceived when the weight repetitively moved compared with single motions.

For the *front* target position, an interaction was observed between the trajectory and speed. A lower dominance was perceived when the weight slowly moved along the direct path compared with fast movements ($t(193) = 2.98$, $p = .003$, $d = .70$).

Intentions

A significant main effect of the repetition for each target position was observed. When the weight repetitively moved, the participants perceived a stronger intention compared with a single movement.

For the target positions *ua_side* and *op_side*, the effect of the trajectory was also significant. Post-hoc comparisons using the Tukey HSD indicated that the perceived intentions for the direct path to the *ua_side* position was weaker than that for the indirect path in which the weight passed the *front* position (*ua_side-indirect1* $p = .014$). For the *op_side* position, the perceived intentions for the direct path were also weaker than that for an indirect path in which the weight passed either the *front* (*op_side-indirect1* $p = .054$) or *ua_side* (*op_side-indirect2* $p = .015$) position.

7.4.3 Design Recommendations based on Parameter Results

Below, we discuss the obtained parameter results and summarize design recommendations for weight shift patterns. We also report on an additional analysis about correlations between perceived emotions and intentions.

To express pleasure, move the weight quickly to the front: With the target position *front*, significant parameters were found for all three emotional states and intentions. However, with the other two target positions, *ua_side* and *op_side*, we did not find any significant parameter for the pleasure perception. The results suggest that the participants' perception of pleasure was significantly affected by the speed parameter, and therefore controlling the speed parameter is presumably effective for designing a weight shift that exhibits a pleasure emotion. However, the results also suggest that *slow* and *repetitive* weight shift patterns may cause displeasure depending on the trajectory, and we have to be careful for these patterns.

To express arousal, apply centrifugal force repetitively: Designing a trajectory is important. To express that the robot is aroused, the weight should pass through the *ua_side* or *op_side* positions to make the robot sway in the *left–right* direction. Furthermore, exhibiting centrifugal force by controlling the rotational movement of the weight, together with controlling the repetition parameter, is presumably effective for producing perceptions of high arousal states. Particularly, in case of a large centrifugal force, if the weight moves to the *ua_side* or *op_side* position rapidly, the perception of arousal can be enhanced.

To express dominance, use an indirect/long trajectory: The results suggest that taking indirect trajectories is presumably effective for producing perceptions of high dominance states. Specifically, the use of long paths to the target position can enhance the dominance; the results showed that the perceived dominance for the *op_side-indirect2* and the *ua_side-indirect2* patterns (the longest paths tested) was greater than that for the other conditions. By contrast, if we want to design a weight shift that exhibits a low dominance or submissive emotion, having a *direct* trajectory with a *slow* speed would be a nice approach. In addition, fast weight shifts can enhance the perception of dominance when the weight moves to the target positions *ua_side* or *op_side*, and repetitive motions can also be effective for the *op_side* position.

Perception of intentions maybe enhanced by repetition and indirect trajectories: To indicate that a robotic gadget is attempting to express something (designing intentionality), controlling the repetition is presumably effective. If the gadget repeats a series of continuous movements, then this may help conveying intentions to the users. This finding is consistent with previous reports on intentional movements [152]. Moreover, because the effects of the direct path to the target positions *ua_side* and *op_side* were weaker than those of indirect paths, choosing an indirect path maybe better to enhance the gadget's capability of conveying intentions.

The *front* target position maybe the first choice in conveying intentions that are associated with various emotional states: For each target position, a multiple regression was calculated to predict the perceived intentions based on pleasure, arousal, and dominance. Significant regression equations were found for each target position (*front* $R^2 = .19$, $F(3, 201) = 15.6$, $p < .001$; *ua_side* $R^2 = .12$, $F(3, 192) = 8.75$, $p < .001$; *op_side* $R^2 = .17$, $F(3, 199) = 13.9$, $p < .001$). For the target position *front*, all of the dimensions of the emotional states predicted the perceived intentions (pleasure $\beta = -.16$, $p = .014$; arousal $\beta = .23$, $p = .002$; dominance $\beta = .21$, $p = .005$). However, only the arousal dimension predicted the perceived intentions for target positions *ua_side* ($\beta = .26$, $p < .001$) and *op_side* ($\beta = .45$, $p < .001$). These results suggest that designing the weight shifts such that the weight moves to the *front* position maybe effective to ensure that the user perceives the various emotions and recognizes the intentions of the robotic gadget in trying to convey those emotions. Similarly, the *arousal* emotion could be well perceived with intentionality in case where the target position is *ua_side* or *op_side*.

7.4.4 Identifying the Semantics of Weight Shift Patterns

We analyzed how each of the weight shift patterns can represent emotions, with a particular focus on denoting the haptic stimuli, by using the emotion-denoting terms proposed by [137]. In [137], 151 words were defined as the 3D coordinates of pleasure, arousal, and dominance (PAD), and we referred to the positional relationships between those words and the ratings of the emotional states for each condition to determine the semantics of each weight shift pattern. However, the dominance dimension in the PAD model is often omitted (e.g., [170, 174]); thus, we applied the P-A dimensions for this analysis.

For this purpose, we first filtered only conditions with a small dispersion in ratings for pleasure and arousal. For the index, the average distance from a centroid ($\bar{d}$) was used. We also performed a cluster analysis using the k-means method to explore conditions in which two different interpretations are observed among the participants. The pseudo *F* index [19] was used to describe the ratio of between-cluster variance to within-cluster variance.[5] A large pseudo *F* value indicates that the dispersion within a cluster is small and that the distance between clusters is large.

[5]The equation was given as follows:

$$Pseudo\ F = \frac{BGSS}{K-1} / \frac{WGSS}{N-K}. \tag{7.2}$$

Furthermore, we attempted to denote the intentions of OMOY by referring to the scores of perceived intentions and the participants' descriptions for each weight shift pattern, which were obtained through the elicitation interview procedure.

Single-cluster analysis

We consider the four conditions (i.e., approximately top 10 %) with the smallest $\overline{d}$, which were *front-indirect2-fast-single* ($\overline{d}$ = 1.18), *ua_side-direct-fast-repetitive* ($\overline{d}$ = 1.27), *front-indirect1-slow-repetitive* ($\overline{d}$ = 1.38), and *op_side-direct-fast-single* ($\overline{d}$ = 1.49).[6]

The centroid and perceived intentions of *front-indirect2-fast-single*, *ua_side-direct-fast-repetitive*, and *op_side-direct-fast-single* had the smallest, second-smallest, and fourth-smallest $\overline{d}$ values at (pleasure, arousal, intentions) = (5.00, 5.00, 3.75), (4.94, 5.76, 3.88), (4.65, 4.35, 3.17). These values indicate that neutral emotions and weak intentions were perceived for the weight shift patterns. In addition, in these weight shift patterns, participants did not mention anything related to the emotion-denoting terms [137] which were matched around the centroids. Thus, we labeled these weight shift patterns as "unintentional movements with neutral emotion."

For the weight shift pattern *front-indirect1-slow-repetitive*, the centroid and perceived intentions were scored as (pleasure, arousal, intentions) = (3.59, 6.59, 5.76), and the emotion-denoting term [137] located closest to the centroid was *"embattled"* (Figure 7.6). One participant commented that *"(The robot) looks a little uncomfortable"*, and 65 % of the participants commented that the robot was trying to express such a feeling to the user: for example, *"I felt like the robot was complaining to me."* and *"I felt strongly denied by the robot, and it was also pressing for my answers."* Therefore, this weight shift pattern can indicate an embattled state, and may also be effective for intentionally conveying the emotion to the user.

Two-cluster analysis

The k-means clustering and index results indicated that the occurrence of opposing opinions on the perception of emotions. The four conditions with the largest pseudo F values were *ua_side-indirect1-fast-repetitive* (*pseudo F* = 60.4), *ua_side-indirect1-slow-repetitive* (*pseudo F* = 27.4), *ua_side-indirect2-fast-repetitive* (*pseudo F* = 26.8), and *op_side-indirect2-fast-repetitive* (*pseudo F* = 25.7).[7]

(BGSS: between-group sum of squares, WGSS: within-group sum of squares, N: number of samples, K: number of clusters)

[6] The values of $\overline{d}$ for all conditions are provided in Appendix A.

[7] The values of *pseudo F* for all conditions are provided in Appendix A.

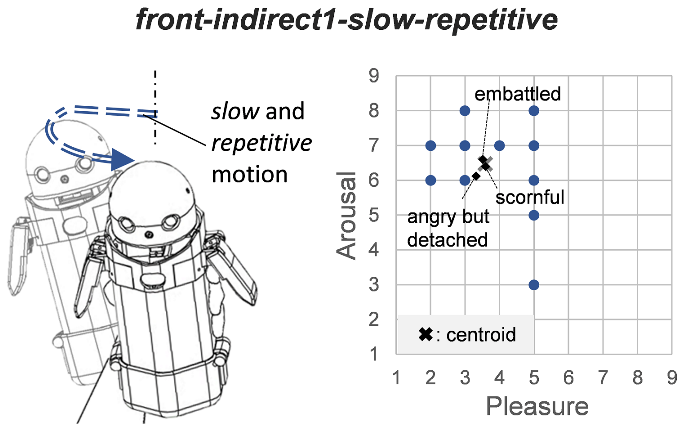

Fig. 7.6 (Left) Behavior of OMOY for the weight shift pattern *front-indirect1-slow-repetitive*, which had the third-smallest $\bar{d}$ value. (Right) Raw data, the centroid, and the emotion-denoting terms that are the closest to the centroid.

Ua_side-indirect1-fast-repetitive had the largest pseudo *F* value, and we gained two clusters (top of Figure 7.7). Near the center of the first cluster (blue dots in top of Figure 7.7), *"fearful"*, *"terrified"*, and *"hate"* terms [137] were plotted, and 78 % of the responses for this cluster interpreted the weight shift as an intentional behavior for expressing a strong refusal: for example, *"It seems like a movement in which children are refusing something by throwing a tantrum."* or *"He is trying to escape from the hand by bending his back."* In addition, some participants perceived the intentions of conveying an urgent message to the user: *"(The robot is) trying to convey an urgent message to me."* or *"It seems to convey an alarm. He is indicating something urgent, like an earthquakes."* Therefore, the first cluster can be denoted as a weight shift pattern for conveying messages with strong refusal or urgency, with strong intentions. By contrast, in the second cluster (red dots in top of Figure 7.7), no comments are related to the emotion-denoting terms. However, 50 % of the participants perceived the intentions of OMOY as trying to express interest or joy: for example, *"It feels like a dog running towards what he is interested by taking the lead."* or *"He is expressing happiness and gratitude."* Based on the center of the cluster and the participants' descriptions, this cluster can be denoted as an emotional state with intermediate pleasure and arousal levels, which are sometimes represented as interest or joy.

Ua_side-indirect1-slow-repetitive had the second largest pseudo *F* value; this weight shift pattern was a slower version of the pattern with the largest pseudo *F* value. Near the center of the first cluster, *"angry"*, *"hate"*, and *"embarrassed"* terms [137] were plotted (bottom in Figure 7.7), and some of the participants' descriptions were

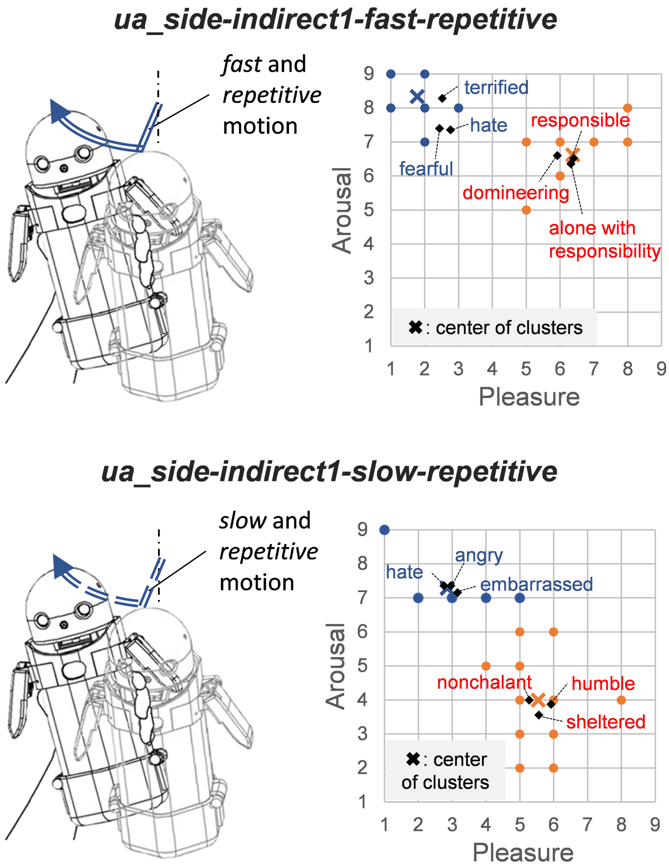

Fig. 7.7 (Top left) Behavior of OMOY for the weight shift pattern *ua_side-indirect1-fast-repetitive*, which had the largest pseudo F value. (Bottom left) Behavior of OMOY for the weight shift pattern *ua_side-indirect1-slow-repetitive*, which had the second largest pseudo F value. (Top and bottom right) Raw data for each condition, cluster centers, and the emotion-denoting terms closest to the center of each cluster.

related to these emotions: for example, *"The robot was trying to run away from being tickled."* or *"I think the robot was trembling slightly, and it was frightened."* In this cluster, 71 % of the participants perceived intentions, but each participant had a different interpretation of the stimulus. Thus, this cluster can be denoted as an expression for displeasure and arousal states, such as *"angry"*, *"hate"*, and *"embarrassed"*, with the feeling that OMOY is trying to express something to the participants. In the second cluster, 55 % of the participants did not perceive the intentions of OMOY, but many of them compared this weight shift to the behavior of small animals: *"It feels like a pet getting close to my hand."* or *"If I compare it to a cat, it feels like it is purring."* By contrast, the participants who perceived intentions commented that the intentions were to attract attention to OMOY: for example, *"It seems that he wants my attention,* *maybe he wants to talk with me. But, he is calm and seems like an adult."* Considering the center of the cluster, the emotion-denoting terms, and the participants' comments, this cluster can be likened to the behavior of small animals that express pleasure and calm states and may sometimes be useful for attracting the attention of the user.

The weight shift patterns *ua_side-indirect2-fast-repetitive* and *op_side-indirect2-fast-repetitive*, which had the third and fourth largest pseudo F values, showed similar cluster plots (Figure 7.8). These patterns were symmetrical with respect to the target position and trajectory, and the speed and repetition were the same. The centers of the first clusters in these conditions are close to each other, and the participants' comments were also similar: for example, *"The robot is feeling uncomfortable, but I don't know what it wants to say. It was trying to tell me something."* or *"The robot is quite stressed and complaining (me or someone)."* In addition, several participants described these movements as a struggle with stress, such as *"a movement of a rat running rampage in a bag."* Therefore, based on the center of the cluster, the emotion-denoting terms, and the participants' comments, these clusters can be denoted as an explosive action that strongly conveys emotions of *"terrified"*, *"fearful"*, *"hate"*, and *"angry"* [137] to the user.

For *ua_side-indirect2-fast-repetitive*, the emotion-denoting term [137] closest to the center of second cluster was *"aroused"*, and we obtained participant comments related to that term: for example, *"It feels like a dog is coming to me with joy and excitement."* By contrast, for *op_side-indirect2-fast-repetitive*, no emotion-denoting terms related to the comments are plotted in Figure 7.8. However, for this weight shift pattern, 80 % of the participants perceived the intentions of OMOY as trying to express joy or happy emotions to the participants: for example, *"It seems to be running and playing around my foot to convey its pleasant feeling."* or *"He is excited, and happy or he wants to jump or he wants to play."* In this condition, the percentage of the participants who perceived intentions was higher than the case with *ua_side-indirect2-fast-repetitive* (44 %). Therefore, the second clusters of both conditions can be denoted as weight shift patterns that express joy or excitement, but the latter may also convey a powerful intention that the gadget is trying to express such emotions to the user.

Overall, we identified weight shift patterns that can express specific emotions and intentions. For some weight shift patterns, opposing interpretations were found among the participants. The meanings represented by these weight shifts are expected to be clear and uniquely defined when combined with other modalities, such as hand gestures, facial expressions, and speech dialogues.

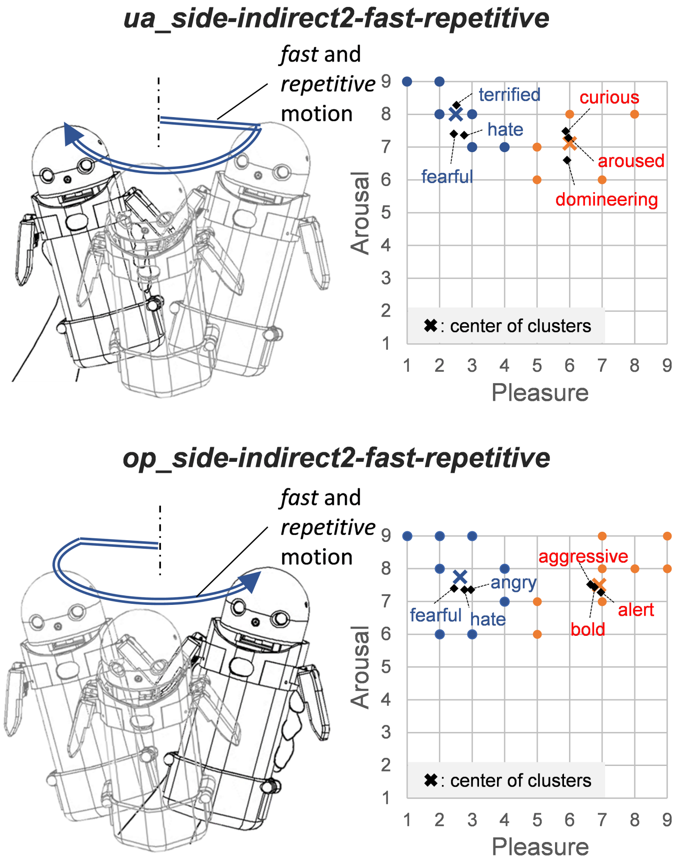

Fig. 7.8 (Top left) Behavior of OMOY for the weight shift pattern *ua_side-indirect2-fast-repetitive*, which had the third largest pseudo *F* value. (Bottom left) Behavior of OMOY for the weight shift pattern *op_side-indirect2-fast-repetitive* which had the forth largest pseudo *F* value. (Top and bottom right) Raw data for each condition, cluster centers, and the emotion-denoting terms closest to the center of each cluster.

7.5 Limitations, Future Works, and Applications

7.5.1 Contextual Factors

In this study, we did not provide participants with a detailed narrative frame for OMOY (we just introduced it to the participants as a communication robot). As was discussed in previous literature [17], human perception on robot emotions is sensitive to narrative framing factors. In this study, we attempted to collect the open perceptions of the participants by not specifying the narrative frame; however, the results have to be interpreted with considering the potential effect caused by the narrative framing factors.

According to the affective grounding perspective that was introduced in human-robot interaction literature [69], *"emotion (how behavior is interpreted emotionally) and emotion regulation (how the emotional meaning of behavior is re-adjusted through repair) are not only internal processes but that can be seen as interpersonal processes that are jointly coordinated by participants of an interaction."* As mentioned in the previous paragraph, we did not clearly specify the context behind the robot. Therefore, participants could have experienced a difficulty in interpreting the robot's emotions, which may be viewed as an initial phase in the affective grounding. Among a total of 648 cases, there were 29 cases in which some of the participants reported such difficulties and could not answer to the questionnaire items. In 12 of those cases, the participants commented that they perceived purely mechanical or inanimate movements without any sort of biological agencies, such as *"it feels like a rugby ball bouncing," "it was like a machine changing its gear,"* or *"HDD (hard disk drive) noise."* In other 10 cases, the participants felt that the movements were too complex to make any comment on. Finally, the other seven cases include four cases reporting malfunctions (in fact not broken) and three cases commenting that the movements were too small to grasp them. It will be an interesting future research to investigate how those interpretations are changing or re-adjusted through the continuous use of OMOY across multiple situations.

7.5.2 Qualitative Analysis

Related to the content that was discussed in the previous paragraphs, an important future work is to investigate the participants' open comments by using qualitative analysis methods. So far, we have confirmed that their descriptions can be classified into, at least, (1) emblems, (2) illustrators [34], (3) cognitive processes, and (4) impressions for subtle posture changes that were caused by weight shifts. It would likely be necessary to make use of multiple qualitative analysis methods to deal with all those descriptions.

7.5.3 Other Limitations

We have to report several considerations with respect to the scalability of our study results. The results of this study were based on the characteristics of our prototype; thus, the results may not hold under changes in parameters of the gadget, such as the appearance, shape, and materials. For future works, we are interested in testing the weight shift functions of different gadgets, for example, by testing a gadget with a simpler appearance, such as a cylinder or cubes, or another gadget with a more human-like appearance, such as a baby doll.

In addition, the number of attributes for each parameter in the elicitation study may not be sufficient. For example, we did not test on ease in/out movements. In our setting, it seemed difficult to distinguish small velocity variations; however, with bigger gadgets, they could be perceived. Because the goal of our study was to explore the effective parameters for weight shifts, we set two or three attributes for each parameter. To strengthen our results, a follow-up study is needed to investigate the effects of each parameter more in detail.

Human factors, such as gender differences or personality traits, should be considered. In particular, the evaluations for social robots can differ depending on the personality traits of the user [173].

The servo noise of the robot may have affected the results. In this study, the movements of the actuator were completely invisible. To compensate for the lack of visual cues in assessing the emotional state and intentions of OMOY with other cues, the participants may have become sensitive to the noise factor (audio cues). In the elicitation study, a few participants mentioned an evaluation bias due to the servo noise. Verifying the effect of servo noise maybe necessary or can be an interesting topic in future works.

7.5.4 Vision for the Future: Social Mediator Robot

Considering the future application of this study, the first thing we have to do next is to study the effects of weight shifts combined with other robotic behaviors such as gestures or speech dialogues. We aim for a scenario in which a robotic gadget serves as a ***social mediator*** that facilitates human communication (Figure 7.9). One use case is remote messaging between elderly people and their family members who live separately. To prevent elderly people from being socially isolated, the role of messaging is becoming very important. However, sometimes it is difficult for elderly people to reveal their true emotions [27, 92]. On the other hand, a recent study reported that a social robot could well facilitate the self-disclosure of elderly people in remote communication [111, 113]. Therefore, we expect that a robotic gadget equipped with the function of enhancing messages by using weight shifts, gestures, and speech dialogues would provide a promising solution for these people.

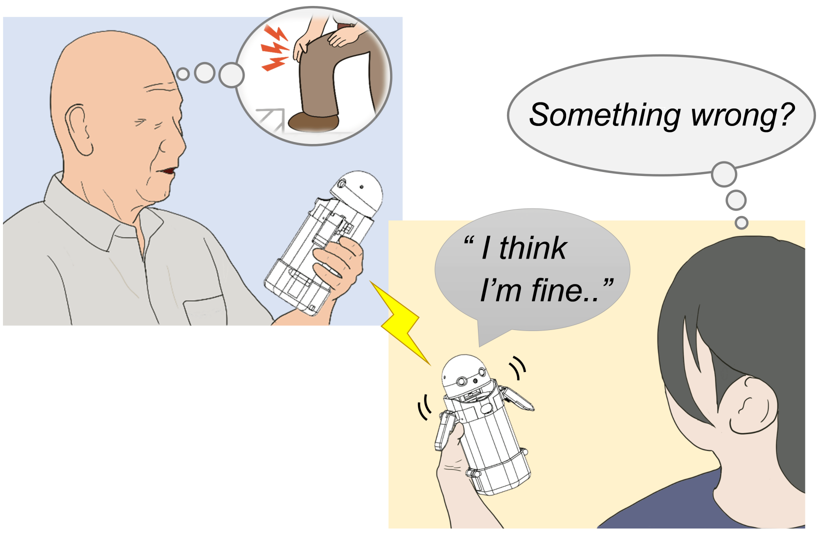

Fig. 7.9 A future use case. OMOY could be used as a *social mediator* for humans. It could help people sending/receiving messages that contain subtle but important information that is sometimes not so easy to express by words or voices. For example, we assume remote communication involving elderly people who live separately from his/her family members.

Chapter 8

Effects of The Internal Weight Movements of Social Mediator Robot on Human Messaging

From the embodied perspective on cognition, the weight-based interaction channel of handheld devices can influence users' judgements and decisions. Jostmann et.al. suggested that the abstract concept of importance is grounded in bodily experiences [67]. Some important results were obtained from the studies conducted: holding a heavy clipboard increased judgments on the monetary value and made participants consider fair decision-making procedures as more important. Similarly, Ackerman et.al. explored how incidental heaviness sensation affects human decisions [1]. As a result, heavy objects made job candidates appear more important: participants using heavy clipboards rated the candidate as displaying a more serious interest in the position. These findings suggest that, in principle, communicating through weight conveys the seriousness of the robot. Therefore, if an appropriate weight shift is expressed along with robot speech, the user may listen to the speech more seriously than the case no weight shift is expressed.

Therefore, in this chapter, weight shift expression of mediator robot was examined in a controlled HRI study involving 94 participants. By using a context scenario, the participants were manipulated to be frustrated by a message sent from another person. OMOY reported the message while providing its opinion to each participant on how to deal with their frustrations. One of the three opinions was presented to each participant: (1) OMOY suggested that the participant should suppress their anger, (2) OMOY showed empathy to the participant, and (3) OMOY avoided providing some particular comments (the robot tried to be a bystander). During

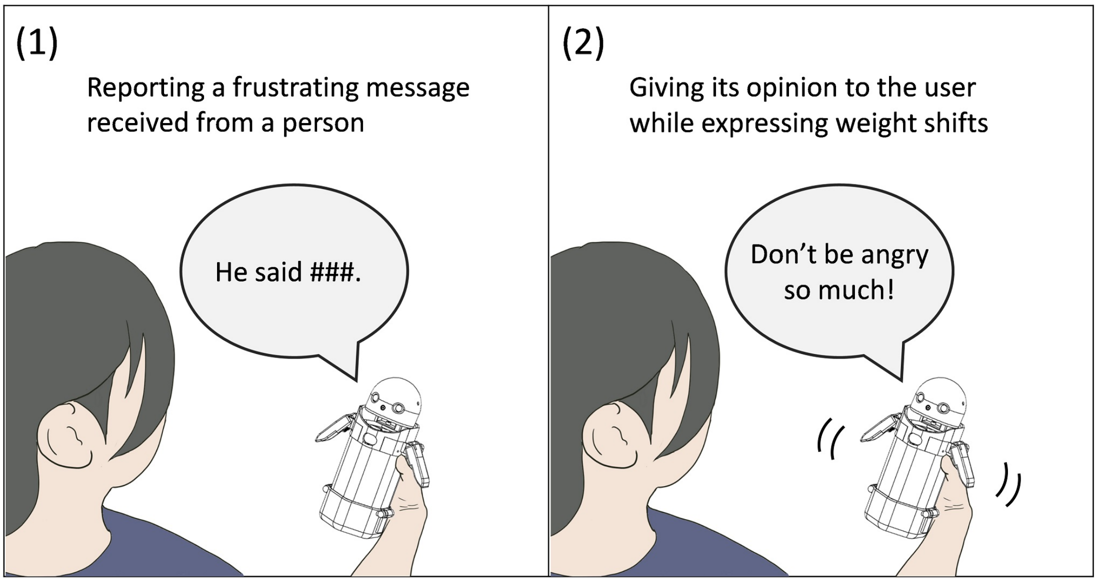

Fig. 8.1 Robot intervention. A mediator robot reports a frustrating message received from a person followed by giving its opinion. The robot can also express internal weight movements (weight shifts). By expressing appropriate weight shifts along with its speech, we hypothesize that the serious intention of the robot can be enhanced, thereby influencing the user's negative affective state.

the expression of its opinion, OMOY exhibited weight shifts to half the number of participants (Fig.8.1). Then, we questioned the participants and analyzed the obtained results to answer the following research questions:

- RQ1: How much can the user's anger, revenge and avoidance motivations be suppressed by the mediator robot exhibiting weight shifts?
- RQ2: Does exhibiting weight shifts affect the user's recognition about the seriousness of the robot? If so, does this feature relate with the results for RQ1?
- RQ3: How does the effect of weight shifts differ depending on the opinion type?

The contents of this chapter are based on the following accepted paper:

- Yohei Noguchi, Hiroko Kamide, and Fumihide Tanaka. Weight Shift Movements of a Social Mediator Robot Make It Being Recognized as Serious and Suppress Anger, Revenge and Avoidance Motivation of the User. Frontiers in Robotics and AI (accepted).

8.1 Robot Platform

The platform used in this study is OMOY, a handheld robot specifically developed to study weight shifts and speech dialogues. OMOY presents weight shifts by moving its internal weight. More specifically, a 250 g tungsten weight is attached to a weight carrier unit, allowing the weight to move along a 2D planar space, thus, the robot provides the weight shift perception to the user who holds the robot. For this study, we provide a little modification to this unit. A linear metal guide rail was applied to achieve smoother translational movements and a Dynamixel XC430-W150T servo motor (1.6 Nm at a 12 V with 1.4 A) was installed on the rotational mechanism to achieve more durability (Figure 8.2). Besides the weight shift expressions, OMOY has basic expression capabilities of hand/head gestures and speech dialogues, similar to other social robots. The dimensions of OMOY are approximately 240 mm (H) × 125/230 mm (arm closed/arm open) (W) × 95 mm (D) and it weights 725 g.[1] The appearance of the OMOY was designed to minimize the influence of prior knowledge of existing commercial robots, thus, it has a simple appearance and body shape. A full description of the mechanical design is found in [110].

8.2 Method

We investigated the effect of robot behaviors on the user's negative affective states in a text messaging using weight shifts. Thus, we conducted an HRI study (N = 94) in which OMOY served as a remote communication interface between humans (Figure 8.3). Participants were provided a specific context scenario that got them frustrated due to a message from their friend (described in Section 8.2.1). The message was read out by OMOY using its voice-synthesizing function, thus, it did not contain any social cues linked to the message sender. Upon reporting the message, OMOY verbally gave its opinion randomly chosen from the three dialogue scripts: (1) the robot suggests that the participant should suppress his/her anger, (2) the robot shows its empathy to the participant, or (3) the robot avoids providing some particular comments. During the expression of its opinion, the robot exhibited weight shifts to half the numbers of participants (other robotic body movements, such as head/arm gestures were not presented). The study was between-participants design, and the measurement was conducted by questionnaires after each interaction.

[1] It gained 5 g from the original prototype reported in [110] due to the update of the weight carrier unit.

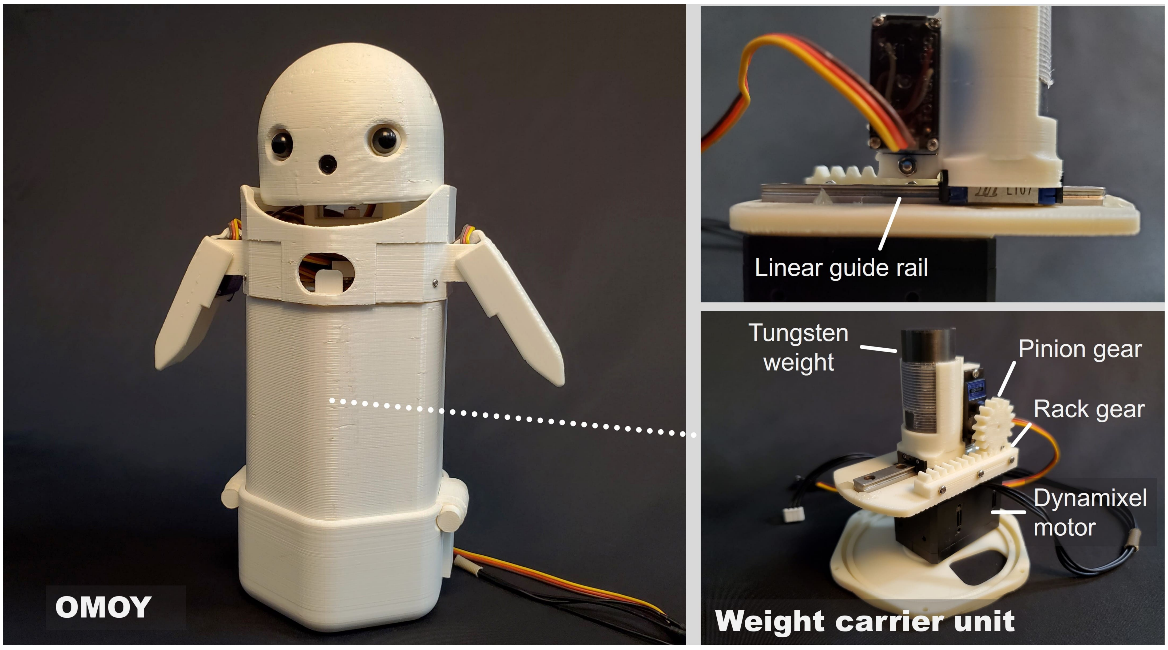

Fig. 8.2 Robot platform, named OMOY, used in this study. A 250 g tungsten weight is attached to the weight carrier unit, which allows the weight to move along a 2D planar space. We modified the weight carrier unit from the original version reported in [110]: a linear guide rail and a Dynamixel motor were installed.

8.2.1 Context Scenario

To control participants' mental states to be frustrated in a messaging context, the following scenario and the accompanying message were given to each participant by a paper.

> *"You had an appointment with your 'friend A' to go to a movie. Today is a very hot and humid day in midsummer. You have come to meet A at the promised time, then decided to sit and wait for A in the shade under the scorching sunshine. However, A doesn't appear and A is holding your tickets. You are already getting angry with A who does not even text you. About an hour passed after the promised meeting time, you received a message from A." The message reads: "I'm sorry, I am late. The appointment slipped my mind. Can you wait another hour?"*

Context scenarios that make participants frustrated due to the tardiness of others is often used in psychological assessment e.g., [134]. In designing our scenario, we modified and applied a scenario used in a Japanese study involving 183 graduate

Fig. 8.3 The experiment was conducted at a booth constructed in a cafeteria in the University of Tsukuba. Each participant was asked to hold OMOY and tested one of its behaviors generated by speech and weight shifts. An experimenter took a seat in front of the participant.

and undergraduate students [76].] In this scenario, the part "*in the shade under the scorching sunshine*" is used to control the physical load associated with each participant. To minimize both the ceiling and floor effects, a moderate level of the physical load was presented in our context scenario[2].

In the message sent by *friend A*, there was a statement explaining the reason for the tardiness. To identify what reasonable statement to be included, a preliminary survey was conducted. From the survey involving 17 participants, it was revealed that recipients felt strong anger when the sender explicitly informed them of forgetting the appointment. Thus, we included the phrase in the message.

8.2.2 Design of Robot Intervention

Verbal Expressions

The robot gave its opinion to each participant about how he/she should deal with the message. We designed three opinion types for this study based on the roles of a

[2]In case of the strongest stimulus, "stand and wait for A under the scorching sunshine", and, in case of the weakest stimulus, "sit and wait for A in a coffee shop nearby" were used in [76] accordingly.

third party in a conflict. Third parties are known to act to support one side or not get involved in conflicts [22, 59].

- Opinion type 1 (suppressing anger): OMOY sided with *friend A*. It pacified the participant to regulate his/her anger and wait for the friend, by speaking *"It is not good to get angry at the person right away, so you should wait for him/her."*
- Opinion type 2 (showing empathy): OMOY sided with the participant. It affirmed the participant's anger and showed an empathetic attitude to the participant, by speaking *"Because you have already been waiting for an hour, it's natural for you to get angry. So you don't have to wait any longer."*
- Opinion type 3 (no comment): OMOY did not take either side of *friend A* nor the participant. In this case, the robot clarifies its position as a bystander by speaking *"I am not involved in this topic, so I don't have any particular opinion."*

For creating the robot's voice, a commercial voice synthesis software called VOICEROID+ was used.

Physical Expressions (Weight Shifts)

This study followed design recommendations by [110]. They developed 36 weight-shifting patterns by using four movement parameters (target position, trajectory, speed, and repetition), and asked 18 participants about their perceptions on the emotions (based on the *pleasure*, *arousal*, and *dominance* (PAD) models proposed in [97]) and intentions (based on the purposefulness dimension discussed in [31]). The design recommendations provided useful knowledge on how each parameter should be modulated to express specific emotions and intentions. For this study, we considered the most practical weight-shifting patterns to be used from the designated scenarios.

By using the design recommendations [110], we designed a specific pattern to emphasize verbal expression using weight shifts. Specifically, from the 36 weight-shifting patterns tested in the study [110], we selected a pattern interpreted as an expression of a neutral emotion with a relatively strong intention for communicating with the user.[3] In the movement pattern, the weight was initially located at the center of the body of OMOY. Then, it moved directly and straight to the front side of the robot facing the user who holds it from the back with his/her hand. The speed

[3] A video showing the weight shift pattern used in this study is available from this link.

parameter of the movement was designed in *fast* by following the definition in [110]: the maximum speed at which the servo motor (SG92B) moves the weight. While the robot speaks its own opinion, as explained in Section 8.2.2, the movements were repetitively performed. The movable weight made six-round trips between the origin and the front side of its body, during which particular delays were inserted. A 100 ms pause was enacted whenever the weight reached either the origin or front of the body of the robot. In addition, a delay of 200 ms was inserted after each of the two round trips ended.

8.2.3 Participants

Ninety-four participants (51 males; 43 females; age: 18-41, M = 21.6, SD = 3.19) were recruited from the University of Tsukuba. They were all Japanese speakers, and every experimental material (e.g., instructions, questionnaires, and speech dialogues of the robot) were provided in Japanese. An experimental booth was set up in a cafeteria of the university, and the recruitment was conducted for passers-by. Posters and banners were placed near the booth to guide interested people in our study. Each participant got a sticky note with a print picture of OMOY on the front cover as a souvenir. The total duration required for each participant was 10-15 min. The study protocol was approved by the research ethics committee of the Faculty of Engineering, Information, and Systems of the University of Tsukuba (2019R317-2), and all participants provided informed consent.

8.2.4 Measurements

Seriousness of the Robot

The weight shift pattern used in this study (explained in Section 8.2.2) makes the user feel strong intention of the robot. Additionally, since [1] reported that participants using heavy clipboards rated job candidates as displaying a more serious interest in the position, it can be considered that weight shifts affect seriousness of the user. Thus, we measured the seriousness of the robot's intention recognized by participants during the interaction, by asking "How serious was OMOY trying to tell its opinion to you?" In answering, a 9-point scale ranging from "1: It was not trying to tell it to me seriously at all" to "9: It was trying to tell it to me very seriously" was used.

Anger

To measure the anger state of participants, we used ten question items (e.g., I am irritated, I want to shout at somebody, etc.) included in the Japanese version [154] of a State-Anger factor in the State-Trait Anger Expression Inventory (STAXI). STAXI [150] is a well-validated psychological scale for measuring human anger based on three independent factors: State-Anger, Trait-Anger, and Anger-Expression. State-Anger represents the intensity of subjective anger at specific stimuli. The ten question items denote behavioral reactions of humans when disturbed by someone. A 4-point scale from "1: strongly disagree" to "4: strongly agree" was used to answer the questions.

To verify that the intervention by the robot influenced the user's anger state, we measured the user's anger state at two time points (before/after the intervention was provided)[4]. In this study, we refer to these two anger states as pre-intervention anger (pre-anger) and post-intervention anger (post-anger), respectively. The pre-anger was measured by presenting the question items to participants and carefully instructing them to assess the mental states they held before the robot intervention (just after reading through the context scenario and hearing OMOY read out the A's message part: *"I'm sorry, I am late. The appointment slipped my mind. Can you wait another hour?"*). For measuring the post-anger, we instructed them to assess the mental states they held after the robot intervention, i.e., after listening to all of OMOY's speech contents including its opinion explained in Section 8.2.2.

Interpersonal Motivations

We hypothesized that forgiveness provided by the participants will differ depending on the robot's behaviors. [96] conceptualized human forgiveness from the perspective of two basic interpersonal motivations: a motivation to seek revenge or see harm come to the offender (i.e., revenge) and a motivation to avoid personal and psychological contact with the offender (i.e., avoidance). The study suggests that the reduction in revenge motivation and avoidance motivations following an interpersonal offense is closely related to forgiveness.

Thus, we measured these motivations using a Japanese-translated version of the Transgression-Related Interpersonal Motivation scale (TRIM) developed by [50]. For example, the question items include: revenge motivation – *I want punishment to be given to A, I want A to get what A deserves*; avoidance motivation – *I would keep as much*

[4]As described in the last paragraph of Section 8.2.5, these were measured at once at the end of each experimental session.

distance from A as possible, I find it difficult to act warmly toward A. In total, 8 question items were presented. In answering them, a 4-point scale from "1: strongly disagree" to "4: strongly agree" was used.

As earlier noted, it is important to focus on reducing those interpersonal motivations when discussing human forgiveness. Therefore, we measured these quantities twice, both before and after the intervention. These pre/post interpersonal motivations were labeled pre-intervention revenge (pre-revenge), post-intervention revenge (post-revenge), pre-intervention avoidance (pre-avoidance), and post-intervention avoidance (post-avoidance). In measuring those motivations, we provided the same instructions as were used in measuring pre/post-anger.

8.2.5 Procedure

During the recruitment of participants, we placed a public notice about our study titled "*An experiment of a dialogue handheld robot*." at the cafeteria where the experimental booth was set up. If a person approached the booth and showed interest in this study, we encouraged them to take a sit on a chair placed in the booth. The study was conducted under face-to-face conditions between an experimenter and each participant. First, the participant completed a survey on their age, gender, on a form displayed on the iPad. Next, we introduced OMOY to the participant as: "*Here is a handheld communication robot, named OMOY. This robot is equipped with a movable weight inside the body. One of its purpose is to mediate human messaging. Today, you will experience an example in which the robot mediates a message.*"

To provide a better understanding of how the interaction with OMOY is like (e.g., about the vocal features and weight shifts), each participant was asked to listen to the self-introduction by OMOY. We instructed them to hold OMOY from the back with their non-dominant hand (similar to holding a smartphone) and to not tilt it by more than 45 degrees to prevent it from lying down. Additionally, from pilot studies, noise from the actuators was an important consideration. Thus, participants wore headphones with a noise cancelling function (SONY WH-1000XM4) to listen to the robot. In the self-introduction, OMOY said: *"Nice to meet you. Thank you for your cooperation in the test today. My name is OMOY. I will help you with your daily messaging. I read out messages received from someone and can give you my opinions when you are about to make a reply. Additionally, I can do weight shifts like this way. Best regards."* At the underlined part, OMOY performed an weight shift pattern including translational and rotational weight movements that were completely different movement patterns used in the main study.

Subsequently, the experimenter showed the context scenario paper (described in Section 8.2.1) to each participant while asking them to imagine their "normal friend" as *friend A* in the context scenario. Because it was known that people easily provide forgiveness to their intimate persons [96], we instructed the participants that *friend A* is neither their best friend, boyfriend/girlfriend, nor a person with whom they want to be close. After the context scenario was given, the participants were asked to hold OMOY and wear the headphone. By sending a command to the robot through a laptop, the experimenter produced each stimulus: first, the robot auditory reported the message sent by *friend A*, then said its opinion with or without weight shifts. At the end of each experimental session, the experimenter passed an iPad to the participant who answered questions regarding their anger state, interpersonal motivation, and seriousness recognition.

8.2.6 Experimental Design and Statistic Analysis

Since the impressions of the robot's intervention were expected to be different depending on the user's affective state, we divided the participants into two groups based on high/low pre-anger using the mean value (with boundary value at 1.85). In the group of participants with low pre-anger, 52 participants were allocated, whereas 42 participants were in the group with higher pre-anger. The t-test ensured that the participants involved in the higher pre-anger group showed stronger pre-anger (M = 2.28, SD = .30) than the participants in the group with lower pre-anger (M = 1.50, SD = .21; $t(70.7) = 14.3$, $p < .001$, $d = .26$). To discuss the extent participants' anger and interpersonal motivation changed before and after the robot intervention, we applied the rate of change (ROC) as dependent variables. Each value of ROC was given by the following equations:

$$ROC_{Anger} = \frac{\textit{post-anger} - \textit{pre-anger}}{\textit{pre-anger}} \tag{8.1}$$

$$ROC_{Revenge} = \frac{\textit{post-revenge} - \textit{pre-revenge}}{\textit{pre-revenge}} \tag{8.2}$$

$$ROC_{Avoid} = \frac{\textit{post-avoid} - \textit{pre-avoid}}{\textit{pre-avoid}} \tag{8.3}$$

We analyzed the effects of independent factors such as the participants' pre-anger (high/low), opinion type, and the presence of weight shifts, on each dependent variable: seriousness recognition, post-anger, ROC_{Anger}, $ROC_{Revenge}$, and ROC_{Avoid}, by performing a $2 \times 3 \times 2$ ANOVA or ANCOVA. Suppose a significant regression coefficient of the gender factor of participants was found, we put this variable into the statistical model as covariance and performed an ANCOVA (otherwise, we used ANOVA).

8.3 Results

8.3.1 Seriousness of the Robot

We examined if participants recognized the serious intention of the robot which exhibited weight shifts. A gender difference was detected, thus we performed an ANCOVA. Results showed a significant main effect of weight shifts ($F(1, 81) = 16.1$, $p < .001$, ${\eta_p}^2 = .17$) indicating that participants agreed that the robot with weight shifts was more serious ($M = 6.10$, $SD = 2.58$) than the case with no weight shift ($M = 4.58$, $SD = 2.62$). Therefore, we see that the weight shift pattern used in this study was successfully designed. Also, there was a significant main effect of the opinion type ($F(2, 81) = 17.7$, $p < .001$, ${\eta_p}^2 = .30$). Then, we performed the Bonferroni test as a post hoc comparison. Results indicated that participants evaluated the robot with no comment (opinion type 3) as less serious, compared with the robots on the other two opinion types ($p < .001$).

8.3.2 Anger

First, we performed ANOVA on the post-anger variable to compare the intensity of anger that the participants held after the robot intervention. The results showed a significant interaction between the factors of the participants' pre-anger and the presence of weight shifts ($F(1, 82) = 9.87$, $p < .002$, ${\eta_p}^2 = .11$). Also, post hoc comparisons using t-tests showed a significant difference in the presence of weight shifts for participants with high pre-anger. Their post-anger was significantly smaller if the robot with weight shifts was used ($M = 1.77$, $SD = .37$), compared with the cases where the robot did not exhibit any weight shift ($M = 2.17$, $SD = .53$; $t(40) = 2.82$, $p = .007$, $d = .46$) (Figure 8.4). However, no significant difference was found in the participant group with low pre-anger. Also, participants having high pre-anger reported significantly larger post-anger than the cases with having low pre-anger: with weight shifts ($t(45) = 4.29$, $p < .001$, $d = .33$); without weight shifts ($t(45) = 7.32$, $p < .001$, $d = .41$) (Figure 8.4).

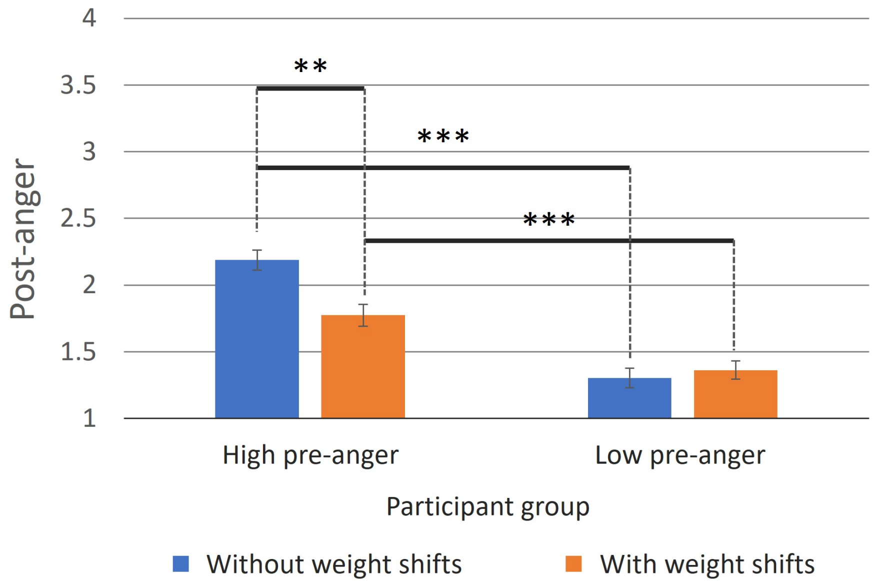

Fig. 8.4 Post-anger comparison (marginal means). In the high pre-anger participant group, participants' post-anger was significantly smaller under the condition the robot exhibited weight shifts compared with the case it exhibited no weight shift (** $p < 0.01$, *** $p < 0.001$).

Next, we performed ANOVA on the dependent variable ROC_{Anger}, to compare how participants' anger level had changed over the robot intervention. The results showed a significant interaction between the factors of pre-anger and the presence of weight shifts ($F(1, 82) = 18.5$, $p < .001$, $\eta_p{}^2 = .18$). Post hoc comparisons using t-tests showed significant differences in the presence of weight shifts for both groups, but the opposite effects were observed (Figure 8.5). In the high pre-anger group, participants' anger was more suppressed in the condition where the robot exhibited weight shifts ($M = -.23$, $SD = .18$) than the case it exhibited no weight shift ($M = -.035$, $SD = .15$; $t(40) = 3.86$, $p < .001$, $d = .16$). However, in the low pre-anger group, participants' anger was more suppressed in the condition where the robot exhibited no weight shift ($M = -.15$, $SD = .14$) than the case it exhibited weight shifts ($M = -.068$, $SD = .16$; $t(50) = 2.07$, $p = .043$, $d = .15$). In cases applying weight shifts, while 23% of anger was suppressed in the high pre-anger group, only 6.8% was suppressed in the low pre-anger group. The difference was statistically significant ($t(45) = 3.28$, $p = .002$, $d = .17$). In cases no weight shift is applied, 3.5% of anger was suppressed in the high pre-anger group, and 15% of anger was suppressed in the low pre-anger

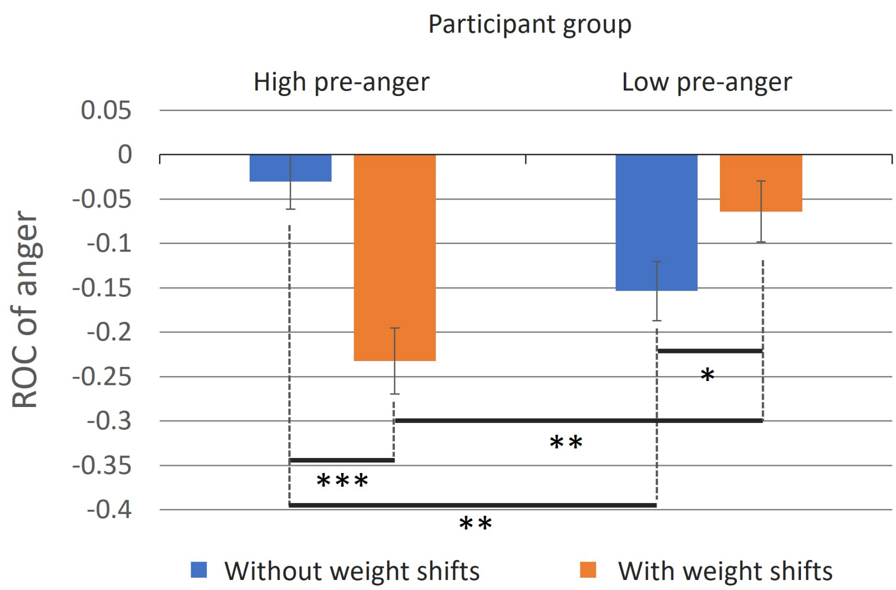

Fig. 8.5 ROC_{Anger} (rate of change of anger) comparison (marginal means). The ANOVA results showed a significant interaction between the factors of pre-anger and the presence of weight shifts. Post hoc comparisons using t-tests showed significant differences in the presence of weight shifts for both groups, but the opposite effects were observed.

group. The difference was also statistically significant ($t(45) = 2.85$, $p = .007$, $d = .14$). No significant effect on the opinion type of the robot was observed.

8.3.3 Interpersonal Motivations

Revenge Motivation

ANOVA was performed on the dependent variable $ROC_{Revenge}$. The results revealed a significant three-way interaction ($F(2, 82) = 3.68$, $p = .030$, ${\eta_p}^2 = .082$). Therefore, we performed a simple interaction test as a post-hoc comparison. An interaction was observed in both participant groups, between the presence of weight shifts and the opinion type: low pre-anger group ($F(2, 46) = 3.06$, $p = .057$, ${\eta_p}^2 = .12$); high pre-anger group ($F(2, 36) = 4.71$, $p = .015$, ${\eta_p}^2 = .21$).

In the high pre-anger group, participants' revenge motivation was significantly reduced at opinion type 2 (showing empathy) with weight shifts ($M = -.22$, $SD = .24$), compared with the case without weight shifts ($M = -.0057$, $SD = .16$; $t(14) = 2.21$, $p = .044$, $d = .20$) (Figure 8.6). In addition, a significant difference was found

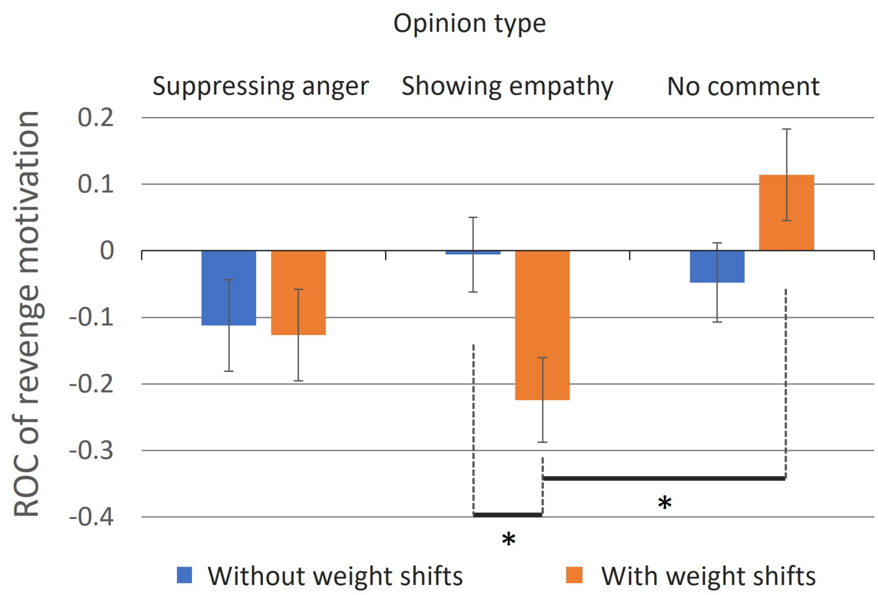

Fig. 8.6 Marginal means of the rate of change (ROC) of revenge motivation in participants having high pre-anger.

($F(2, 16) = 4.49$, $p = .028$, ${\eta_p}^2 = .36$) between two opinion types (2 and 3) when using weight shifts ($p = .029$ given by Bonferroni test) (Figure 8.6).

In the low pre-anger group, participants' revenge motivation was significantly reduced at opinion type 1 (suppressing anger) without weight shifts ($M = -.19$, $SD = .21$), compared with the case applying weight shifts ($M = .11$, $SD = .33$; $t(18) = 2.36$, $p = .030$, $d = .28$) (Figure 8.7). In addition, a significant difference was found ($F(2, 21) = 5.07$, $p = .016$, ${\eta_p}^2 = .33$) between two opinion types (1 and 3) without using weight shifts ($p = .014$ given by Bonferroni test) (Figure 8.7).

Avoidance Motivation

ANOVA was performed on the dependent variable ROC_{Avoid}. The results revealed a significant interaction between participants' pre-anger and the presence of weight shifts ($F(1, 82) = 5.34$, $p = .023$, ${\eta_p}^2 = .061$). Post hoc comparisons using t-tests showed significant differences in the presence of weight shifts in both participant groups.

In the high pre-anger group, participants' avoidance motivation was slightly suppressed when the robot exhibited weight shifts ($M = -.15$, $SD = .19$), compared

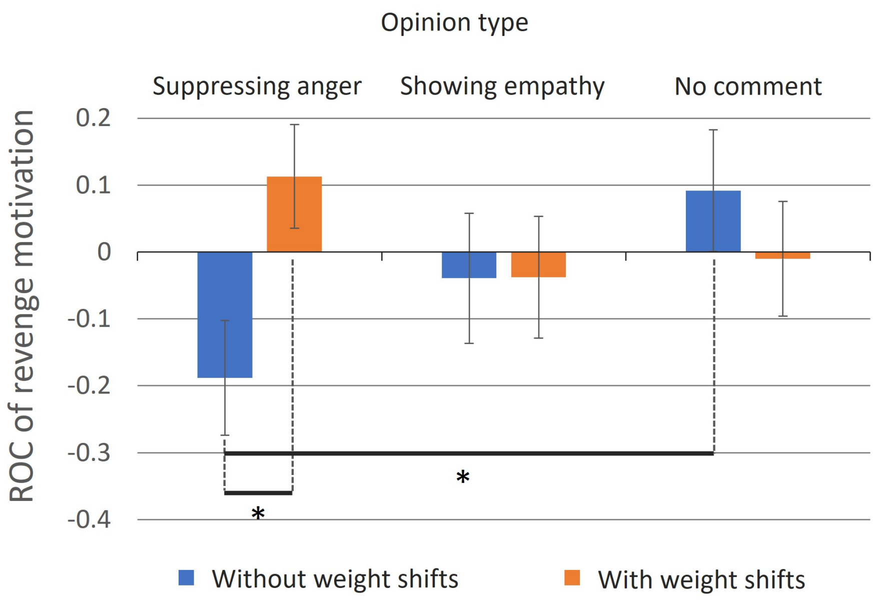

Fig. 8.7 Marginal means of the rate of change (ROC) of revenge motivation in participants having low pre-anger.

with the case without weight shifts (M = −.058, SD = .15; $t(40)$ = 1.68, p = .10, d = .17).

On the other hand, in the low pre-anger group, participants' avoidance motivation was significantly suppressed when the robot did not exhibit weight shifts (M = −.14, SD = .23), compared with the case using weight shifts (M = −.0016, SD = .23; $t(50)$ = 2.08, p = .043, d = .23) (Figure 8.8).

In addition, a significant difference was found between the high/low pre-anger groups when using weight shifts ($t(45)$ = 3.28, p = .031, d = .22).

8.3.4 Regression Analysis

We examined whether the robot's seriousness recognized by the participants affected their ROC_{Anger}, $ROC_{Revenge}$, and ROC_{Avoid} by the regression analysis. In the high pre-anger group, a significant regression was found for each dependent variable (ROC_{Anger} R^2 = .12, $F(1,40)$ = 5.20, p = .028; $ROC_{Revenge}$ R^2 = .12, $F(1,40)$ = 5.21, p = .028; ROC_{Avoid} R^2 = .26, $F(1,40)$ = 13.8, p = .001). Regression coefficients (ROC_{Anger} β = −.028, p = .028; $ROC_{Revenge}$ β = −.028, p = .028; ROC_{Avoid} β = −.038, p = .001) show that the seriousness recognition was negatively correlated with the participants' anger, revenge motivation, and avoidance motivation. However, in the

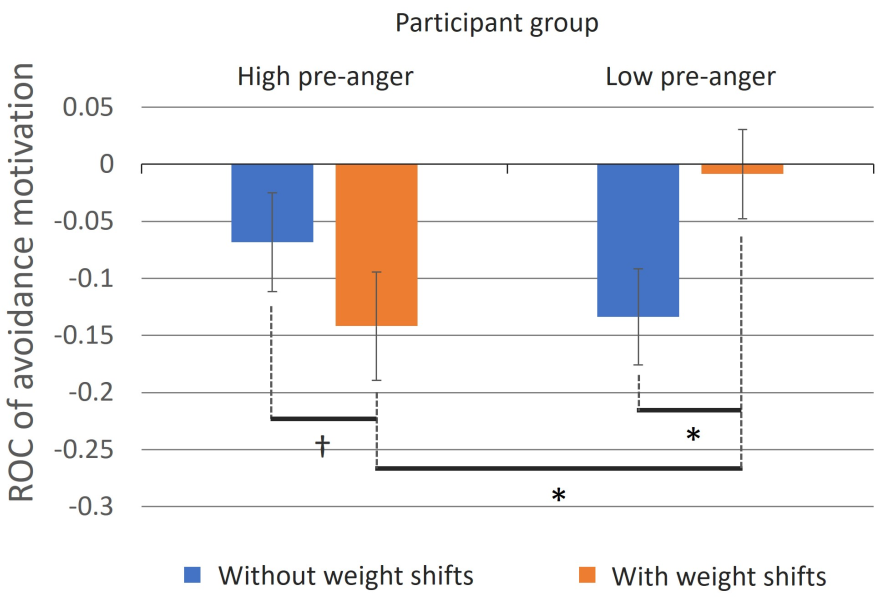

Fig. 8.8 Marginal means of the rate of change (ROC) of avoidance motivation.

low pre-anger group, no significant regression was found. The results suggest that the seriousness displayed by the robot had effects only on the participants having high pre-anger.

8.4 Discussions and Limitations

Exhibiting weight shifts during text messaging was particularly effective for participants having high pre-anger. Their anger was suppressed on average by 23%. Notably, the opinion type did not make a significant difference. Because anger is a very primitive emotion and aroused instinctively, verbal messages may have been insufficient to exert a major impact to suppress it. Rather, the haptic sensations produced by the internal weight movements, or the seriousness of the robot enhanced by such movements may have been dominant in suppressing their anger.

For revenge motivation, a complex interaction was observed that involves the opinion type. In cases where the robot showed empathy to the user in words (opinion type 2) with weight shifts, the user's revenge urge was successfully reduced by 22%. However, we found that in some cases, weight shifts promoted the motivation for revenge, thus, care must be taken in such cases. For example, when the robot expressed its unbiased position (opinion type 3) to participants having high pre-anger, their revenge motivation to the message sender was promoted by weight shifts. Overall, the opinion type 3 brought different impacts on the suppression of the user's revenge motivation compared to the other opinion types. However, this study did not provide strong evidence for explaining why such differences were observed. Future studies are needed to gain deep understanding about the effect brought by the opinion type 3.

For avoidance motivation, the effects of weight shifts were almost consistent with those for the anger state. On average, 15% of the avoidance motivation was reduced if weight shifts were applied in participants having high pre-anger. As [96] suggested, reduction in interpersonal motivations is considered an important clue in discussing people's forgiveness. Thus, our findings provide an evidence that the behavior of mediator robots can potentially induce forgiveness in the messaging context.

Additionally, our study results indicate that OMOY could express seriousness to the user through weight shifts. We attempt to discuss this phenomenon from the viewpoint of costly signaling theory, which has been discussed in evolutionary psychology. The theory proposes that costly signals generated by animals (including humans) may guarantee its honesty [95]. For example, upon receiving a costly apology, the recipient recognizes the sincerity of the apology giver and be more likely to provide forgiveness [117]. In the present study, when OMOY exhibited weight shifts, the entire body movements were visually and haptically displayed, thus the nonverbal signal was recognized as more costly than the case without weight shifts. Consequently, OMOY might be regarded as more serious when it performed weight shifts. When presenting weight shifts to the participants, OMOY had to require the force compensations from them, otherwise, it falls down. The cost for holding the robot was spent by the participants who hold it (in this case, the cost equals to the power consumed at muscles of their arms). However, even they had spent the cost, the robot was recognized as serious. This may imply that participants incorporated the cost spent by themselves for holding the robot into the estimation of the cost spent by the robot. This implication consists with the findings in the embodied perspective on cognition which suggest that the abstract concept of importance is grounded in bodily experiences of weight: heavy objects generate perceptions of importance or seriousness [67, 1].

In this study, some differences were found between two participant groups (having high/low pre-anger). Generally speaking, to behave socially, we humans can intentionally suppress our anger to some extent. Neuroimaging studies revealed that our brain shows specific activation patterns when attempting to self-regulate our anger [124]. However, the magnitude of the motivation for such self-regulation of emotions depends on the intensity of the emotion that the person has. Therefore, the participants having high pre-anger possibly had a strong motivation to suppress their anger. For those participants, the serious attitude of OMOY could have encouraged their motivation for self-regulating their anger. In contrast, the participants having low pre-anger may had little motivation for suppressing their anger, thus the serious intention of the robot exerted little influence on their psychological states. This difference may highlight a unique characteristics of weight shifts in the mechanism of reducing human anger.

A number of studies have been reporting the calming effect of touch in human, animal, and robot interaction [33]. Touches such as stroking, holding, and pushing, so-called *social touch*, replicated by wearable devices and robots can reduce the user's stress [63, 72, 43]. As a future work, it is valuable to study if weight shifts presented by the robot have such a calming effect.

In haptic interactions between existing social robots and humans, haptic sensations occurred mostly on the user's skin or organs close to the contact region (e.g., by temperature [123, 106, 14], texture [61], and vibration [149]). These sensations are cutaneous sensations activated by receptors in that region. By contrast, the robot used in this study provides a dynamic force made by a moving internal weight that activates receptors in a broader region (i.e., muscles, tendons, joints, and organs). Although this study has not provided the result of a comparison between our robot and the one with a simpler mechanism such as vibration, we have an impression that there is a clear difference between the two sensations mentioned above. However, future work is required to discuss the difference in detail with empirical evidence.

There are several limitations in our study. First, we used a simulated context scenario and the results may not hold when other scenarios are used. Second, all measurements were conducted within a relatively short time window. To supplement our findings, further empirical studies in real-world messaging are needed. Finally, the characteristics of the robot platform underline the results of this study. The results may vary under changes in parameters of the robot, such as appearance and its material. For future work, we are interested in applying the weight shift function into other handheld gadgets such as stuffed animals and cushions.

Chapter 9

Conclusion

Social mediator robot, discussed in this research was conceptualized as *"an intelligent agent that intervenes in human messaging by modifying, augmenting, or generating messages to accomplish communication goals, and is explicitly presented to the communicator as a third party"* in Chapter 2. Through overcoming the limitations of commercial robots with messaging functions such as RoBoHoN [25], this research aimed to design an adaptive and expressive social mediator robot. To this aim, I developed several prototypes of social mediator robot and carried out multiple user studies, including physical HRI studies with laboratory setup and large scale exploratory online surveys. In this section, important findings of these studies are summarized, and suggestions for future research are also provided.

9.1 Overview of Findings

9.1.1 Topics in Which Elderly People Feel Easier to Self-Disclose With Social Mediator Robot

In Chapter 3, the relationship between the robot's specifications and the topics in which the elderly people are encouraged to self-disclose is discussed. After the development of a prototype robot, the effect on self-disclosure of the elderly was studied through an HRI study (N = 21). By comparing three media for self-disclosure (phone, expressive mediator robot, and non-expressive mediator robot), introducing expressive mediator robot, which was perceived as having human-like personality, was suggested to be an effective medium for disclosing in topics concerning *loss experience*. Loss experience is known to be one of the topics that the elderly people do not disclose easily [153]. Thus this study successfully showed the experimental evidence for the feasibility of social mediator robot in the domain of supporting remote communication of the elderly people.

9.1.2 Personality Traits for Social Mediator Robot to Encourage Elderly Self-Disclosure

In Chapter 4, the aspects of the personality perception toward social mediator robot on the elderly self-disclosure was studied. Based on the well-known knowledge on the similarity attraction theory reported in the related field (e.g., [3, 86, 99, 158, 7]), some extension was applied in this study. Specifically, the present study made a further detailed investigation involving extroversion, neuroticism, and human gender. The results indicated that the similarity attraction was observed only in the participant group having high extroversion and low neuroticism. However two of the other participant groups showed similarity repulsion, which is entirely opposite effect of similarity attraction. Even the participants who had low extroversion and low neuroticism showed no significant difference among all of the robots having different personality traits. By summarizing those study results, design recommendations were provided that contribute to personalization of the behaviors of mediator robot so as to encourage the elderly self-disclosure.

9.1.3 How Should Social Mediator Robot Deliver Messages of the Elderly

Chapters 5 and 6 studied the anxiety of the elderly discloser based on the self-presentation theory of social anxiety [84]. I hypothesized that a social mediator robot might be able to suppress the anxiety of the elderly disclosers by presenting them with effective messaging options that would facilitate their self-presentation. To examine this, messaging options were designed through multiple large scale explorative online surveys (N = 1248), and then they were implemented to a robot prototype. In an HRI study (N = 36), two interaction models of social mediator robot were compared (mediator robot 1: when reporting the message, it just repeats the original message contents what the elderly discloser input, by using its voice; mediator robot 2: when reporting the message, it applies preferable messaging option that the elderly disclosers chose). The results showed that the anxiety of the elderly disclosers was significantly lower when the mediator robot 2 was used compared to the other. This suggests that the ability of the mediator robot to report messages can affect the user's interpersonal feelings (such as anxiety), and that the messaging options designed through the exploratory study were effective.

9.1.4 Enhancing Expressiveness of Social Mediator Robot Through Internal Weight Movements

In Chapter 7, a novel hardware for social mediator robot was proposed, specifically designed to study the effects of haptic signals from mediator robots on human messaging. In this study, a handheld robot, called OMOY, that is equipped with an internal weight was developed. A movable weight is implemented inside its body and is controlled by the translational and rotational mechanisms determined by four parameters (target position, trajectory, speed, and repetition). Using 36 patterns of weight shifts generated by combining these four parameters, we conducted an elicitation study to obtain knowledge for weight shift design (N = 18). The results suggest that the weight shifts presented by OMOY can express specific emotions and intentions of the robot. In addition, a mapping between these parameters and the user's emotion recognition was shown. This research is an attempt to open a new dimension in the expression capabilities of social mediator robots.

9.1.5 Effects of the Internal Weight Movements of Social Mediator Robot on Human Messaging

In Chapter 8, an HRI study involving 94 participants was reported. By using a context scenario, the participants were manipulated to be frustrated by a message sent from another person. OMOY reported the message while providing its opinion to each participant on how to deal with their frustrations. During the expression of its opinion, OMOY exhibited weight shifts to half the number of participants. The results showed that the the haptic expression (i.e., weight shifts) of a handheld robot that intervenes in communication as a third party has the possibility to alter the recipient's minds and behaviors. Specifically, results showed that introducing weight shifts together with the robot speech suppressed on average 23% of the user's anger. However, only 3.5% of the anger was suppressed when the weight shifts were not applied. Interestingly, the opinions that OMOY presented to the user did not show strong effects that those of the weight showed. This study presents the novel findings in that it not only examines the human perceptions of the haptic expressions in social robots, but also considers their impacts on human behavior and internal state changes. These findings suggest that weight shifts may be a powerful expression channel for social mediator robots to intervene in people's messaging as a third party.

9.2 Implications and Future Prospects

In this study, adaptive and expressive social mediator robots were developed, and the effectiveness were successfully demonstrated in two communication situations (facilitating self-disclosure in the elderly and mediating interpersonal conflicts). Additionally, from the studies using the prototypes, design knowledge on robot behavior that can influence people's communication was obtained. This may have the potential to improve human communication and interpersonal relationships by being applied to robots that will emerge in the future.

Based on psychological indicators such as people's self-disclosure, which has been used as an indicator of interpersonal intimacy in traditional HRI and CMC, this paper revealed that the adaptive behavior of mediator robots could improve the remote communication between humans. However, currently, humans (not robots) mostly play the role of mediators of other people. I believe that some of the behavioral guidelines of the mediator robots obtained in this study may be useful for improving the efficiency of intermediation, which is still performed by humans. For example, the findings in Chapters 3 through 6 could be transferred to the provision of quality interactions between older adults and care managers (care managers are people who act as mediators between the elderly and the actual care provider). Although the difference between human and robot mediators needs to be discussed, future research could also be conducted from the perspective of developing applications that support humans to act efficiently as mediators based on the behavioral guidelines clarified in this study.

In addition, this study explored if a mediator robot having weight shift movements can affect the psychological state of the user. The robot's body expression produced by weight shifts required no specific external components, such as arms or legs, implying that the internal weight movements potentially reduce the users' anger, etc., without the use of rich body gestures or facial expressions. I believe that the robot's expression modality using weight shifts has the potential to be used in a variety of situations other than message mediation. To verify this, a plug-in weight shifting module has been developed (Appendix B). This module can be inserted into variety of objects such as stuffed toys or cushions. Doing so, it makes the objects as a social partner that enhances audio-visual entertainment, for example. It is expected that the development of social entities using internal weight movements will be further researched and disseminated to society in the future.

On the other hand, in order to popularize mediator robots in the future, it is necessary to extend their interactions to suit various use-cases and target users. As more and more home robots are introduced into the society, there will be situations where messages are asynchronously exchanged not only between remote locations, but also between members living in the same house. In such a case, the following messaging scene can be expected: for example, the robot intervention might be done between a kid shunning other people and his/her parents, or sometimes a robot might need to intervene in a communication between a couple in the middle of a fight. Future robots need to switch their behaviors based on the state and relationship of the communicator. However, to date, there has been little research on such robots. As a result, few datasets have been constructed to design effective HRIs, and there also be a lack of knowledge in the field of human science. In order to realize social robots that can serve as good mediators for human beings, it will be necessary to design behaviors that are considered effective one by one on a case-by-case basis and collect user feedback. Integration of these findings will enable us to extend the available use cases of social mediator robot.

Lastly, the author's vision of social mediator robots is shown in Figure 9.1. If we call mediator robots currently on the market as the first generation, the robots that I aimed to develop in this dissertation are the second generation. This second generation of mediator robots is more adaptive and expressive than the first generation. The third generation of mediator robots, which will appear in the next few decades, should be in the position of managers of interpersonal relationships. More specifically, the robot can even predict the impact of its own actions on the relationship between two people and change its behavior autonomously. It should also have the ability to flexibly adapt to long-term changes in the interpersonal relationship. Future research is needed to expand the autonomous functions of mediator robots in order to realize the third generation of social mediator robots.

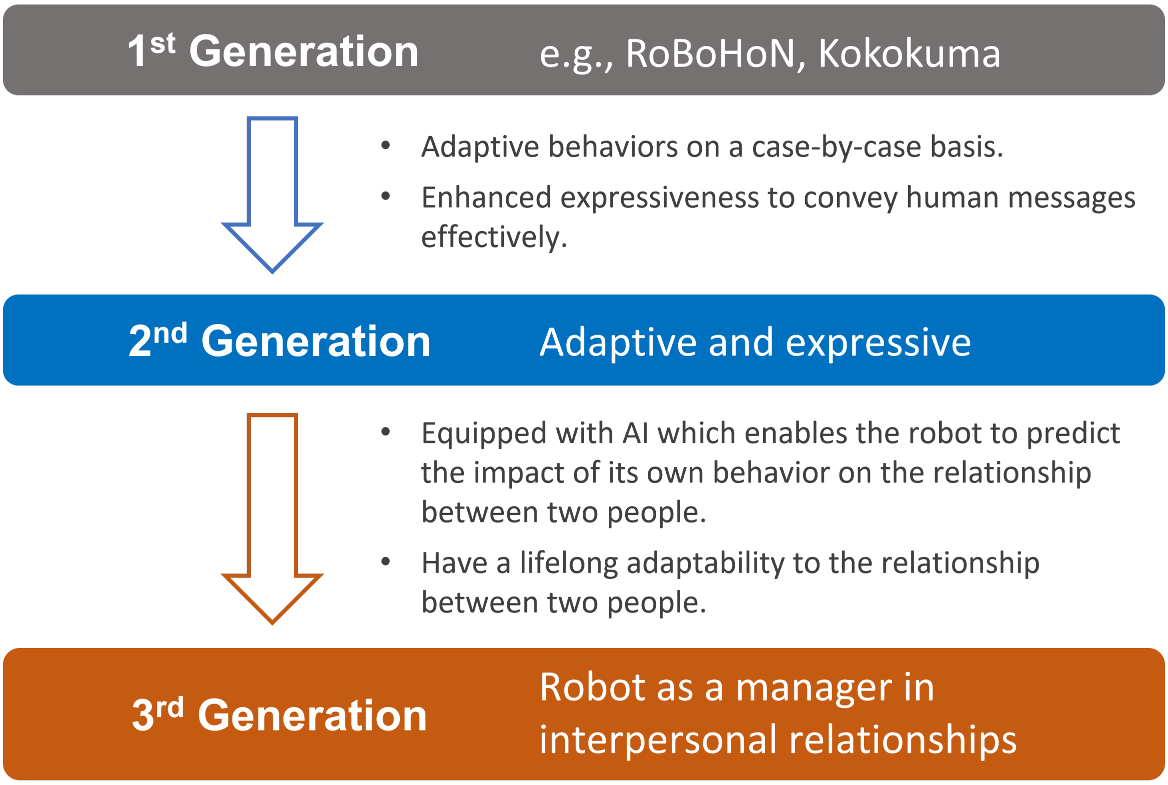

Fig. 9.1 The author's vision of a future social mediator robot.

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Appendix A

Auxiliary Material

Table A.1 Statistical results of the elicitation study in Chapter 7.

Weight shift pattern	M (SD) of perceived emotions and intentions								Cluster index			
	Pleasure		*Arousal*		*Dominance*		*Intentions*		$\bar{d}$	Rank	*Pseudo F*	Rank
front-direct-fast-single	5.22	(1.40)	4.33	(2.20)	4.61	(1.58)	4.22	(2.29)	2.25	28	20.8	9
front-direct-fast-repetitive	5.22	(1.26)	4.89	(1.81)	4.78	(1.44)	5.17	(2.36)	1.94	20	21.3	8
front-direct-slow-single	4.56	(1.03)	4.38	(1.82)	3.29	(1.76)	3.63	(2.33)	1.79	12	21.9	7
front-direct-slow-repetitive	3.82	(1.78)	3.29	(1.76)	3.71	(1.69)	5.18	(2.10)	2.25	29	15.9	13
front-indirect1-fast-single	5.11	(1.60)	5.83	(1.86)	5.28	(1.74)	5.11	(2.42)	2.09	24	10.6	26
front-indirect1-fast-repetitive	5.00	(1.46)	6.76	(1.56)	5.29	(1.53)	5.06	(2.41)	1.84	16	13.8	18
front-indirect1-slow-single	4.75	(1.29)	5.44	(1.67)	5.25	(1.06)	5.38	(2.47)	1.63	7	8.47	32
front-indirect1-slow-repetitive	3.59	(1.18)	6.59	(1.12)	6.18	(1.13)	5.76	(2.70)	1.38	3	8.96	31
front-indirect2-fast-single	5.00	(1.03)	5.00	(1.26)	4.88	(1.09)	3.75	(2.46)	1.18	1	12.6	20
front-indirect2-fast-repetitive	4.39	(2.30)	7.11	(1.41)	6.56	(1.34)	5.78	(2.98)	2.36	31	18.4	10
front-indirect2-slow-single	3.94	(1.57)	5.44	(1.59)	5.63	(1.89)	5.63	(2.22)	1.92	19	9.73	29
front-indirect2-slow-repetitive	4.83	(1.72)	6.33	(1.28)	5.72	(1.78)	6.06	(1.83)	1.87	17	17.7	11
ua_side-direct-fast-single	5.07	(1.21)	4.79	(1.58)	4.71	(1.07)	3.27	(2.19)	1.58	5	10.1	27
ua_side-direct-fast-repetitive	4.94	(0.97)	5.76	(1.20)	5.00	(1.46)	3.88	(2.42)	1.27	2	12.2	22
ua_side-direct-slow-single	4.58	(1.73)	3.42	(1.56)	4.00	(1.71)	4.15	(1.82)	1.99	22	3.70	36
ua_side-direct-slow-repetitive	4.69	(1.45)	3.81	(2.29)	4.44	(2.13)	4.13	(2.33)	2.49	33	22.8	5
ua_side-indirect1-fast-single	4.38	(1.41)	5.31	(1.85)	5.75	(1.69)	5.18	(2.70)	1.84	15	5.52	35
ua_side-indirect1-fast-repetitive	3.94	(2.56)	7.53	(1.18)	5.06	(2.01)	6.24	(2.77)	2.58	35	60.4	1
ua_side-indirect1-slow-single	5.56	(1.15)	4.39	(1.58)	4.78	(1.11)	4.22	(2.65)	1.66	8	12.4	21
ua_side-indirect1-slow-repetitive	4.50	(1.76)	5.28	(2.02)	4.17	(1.79)	5.06	(2.90)	2.34	30	27.4	2
ua_side-indirect2-fast-single	4.94	(1.25)	5.94	(1.48)	5.18	(1.01)	3.41	(1.87)	1.59	6	14.4	17
ua_side-indirect2-fast-repetitive	4.35	(2.12)	7.53	(0.94)	5.29	(1.83)	5.00	(2.65)	1.98	21	26.8	3
ua_side-indirect2-slow-single	5.00	(1.41)	4.94	(1.92)	4.94	(0.90)	4.06	(2.14)	1.89	18	13.3	19
ua_side-indirect2-slow-repetitive	4.76	(2.14)	6.59	(1.80)	5.65	(1.22)	5.71	(2.62)	2.46	32	15.3	15
op_side-direct-fast-single	4.65	(1.06)	4.35	(1.46)	4.76	(0.83)	3.17	(2.28)	1.49	4	16.6	12
op_side-direct-fast-repetitive	5.53	(1.28)	5.47	(1.70)	5.29	(1.40)	4.71	(2.37)	1.83	14	12.0	23
op_side-direct-slow-single	5.50	(1.40)	3.93	(1.38)	4.21	(1.37)	2.93	(2.56)	1.67	9	10.9	24
op_side-direct-slow-repetitive	5.06	(1.53)	4.00	(1.86)	4.25	(1.18)	3.82	(2.27)	2.11	25	9.78	28
op_side-indirect1-fast-single	4.71	(1.36)	5.47	(1.62)	5.18	(0.81)	3.83	(2.75)	1.71	10	10.7	25
op_side-indirect1-fast-repetitive	4.71	(2.31)	6.47	(1.97)	5.00	(1.54)	6.11	(2.56)	2.64	36	22.2	6
op_side-indirect1-slow-single	5.28	(1.36)	4.17	(1.69)	4.11	(1.53)	4.33	(2.14)	1.83	13	9.52	30
op_side-indirect1-slow-repetitive	5.29	(1.40)	5.00	(2.06)	4.18	(1.29)	4.65	(2.09)	2.23	27	15.2	16
op_side-indirect2-fast-single	5.25	(1.44)	4.50	(1.55)	4.75	(1.69)	3.94	(2.35)	1.76	11	5.65	34
op_side-indirect2-fast-repetitive	5.00	(2.54)	7.61	(1.14)	6.11	(1.57)	6.33	(2.11)	2.50	34	25.7	4
op_side-indirect2-slow-single	4.72	(1.56)	4.39	(1.82)	4.61	(1.04)	3.94	(2.15)	1.99	23	15.4	14
op_side-indirect2-slow-repetitive	5.39	(1.79)	5.33	(1.81)	5.28	(1.36)	5.17	(1.92)	2.21	26	7.72	33

Appendix B

A Plug-in Weight-Shifting Module that Adds Emotional Expressiveness to Inanimate Objects in Handheld Interaction

B.1 Introduction

Haptic interaction is becoming the core channel for designing human-robot interaction (HRI). Researchers demonstrated that the sensory of touching with robots influences the users' task performance [147], emotion perceptions [61, 123], and building relationships [74, 169]. Social robots that are already in the market can be seen having such haptic interaction capabilities, enabling them to perform better emotional interactions with users. For example, LOVOT [45] is a companion robot developed and distributed by GROOVE X, Inc. in Japan. The robot has touch sensors over its body and is designed to react to human touch warmly and cutely.

Meanwhile, a novel expression modality for robots has been introduced by internal weight movements [110]. In this approach, a movable weight is implemented inside the body of the robot, called OMOY, and moved by specific mechanical components. Consequently, the robot can express its emotions or other internal states through the weight shifts to the user who holds it. Furthermore, the risk for user injury might be reduced, which always increases when a robot moves its arms or legs physically in a typical HRI manner [140], because the movable weight and its actuators are totally covered with a tough exterior. However, the prototype proposed in [110]

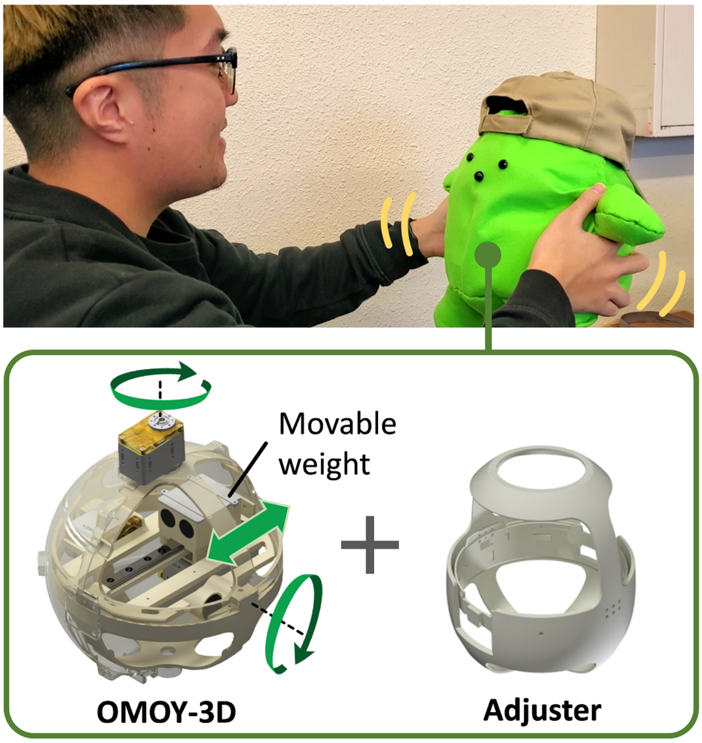

Fig. B.1 An embodiment (stuffed toy-style) of the OMOY-3D module that is plugged in by an adjuster. The module is equipped with a movable weight that controlled by a translational and two rotational mechanisms, thus rendering 3D patterns of weight shifts. During the interaction, the user hears a voice of the robot and makes two handheld contact to feel weight shifts.

remains technically insufficient in several aspects. The main disadvantage is that it can only exhibit two-dimensional (2D) planer weight shifts on the front side of the robot, which is actually insufficient for expressing emotions correctly to the user. In addition, the weight-shifting mechanism of the former prototype was completely embedded in the robot's body. Thus, the effects of the other robot embodiment, to which the weight shifts were given, cannot be verified.

In this work, we developed a new physical component, called OMOY-3D, which can render three-dimensional (3D) weight shift patterns in two handheld interactions (Fig. B.1). A 350 gram of tungsten weight was attached to an internal mechanism that enabled the weight to move around according to a 3D polar coordinate. We adopted a "plug-in" design to allow it to be inserted into a variety of objects (i.e., existing robots and objects, such as stuffed toys or cushions) via the corresponding adjusters. Fig. 2 shows the OMOY-3D with different embodiments.

Fig. B.2 Three variations of OMOY-3D embodiments (left: a stuffed toy-style / center: a cushion-style / right: a basket-style).

No design methodology exists to create 3D weight shift patterns for robot expression. To address this issue, we conducted a study to design effective patterns for expressing emotions that are possibly useful in different contexts. For the design, we first collected 48 draft ideas of weight shift patterns from a sketch-drawing workshop. By qualitatively analyzing these sketches, we obtained eight weight shift pattern designs to express certain emotions based on the theory of the Laban Movement Analysis (LMA) [82].

We implemented these patterns in OMOY-3D and tested them by five participants, to check their feasibility and collect detailed user comments. For the test, we introduced three different embodiments with specific scenarios, where the weight shifts were presented to the user by a) a stuffed toy-style robot that mediated human messaging, b) a cushion-style robot that made the user relax, and c) a basket-style robot that enhanced the user's movie watching experience. Feedback provided useful knowledge with respect to further design guidelines and future research questions.

To summarize, the contributions of this paper are as follows:

- The hardware design of a 3D weight-shifting module that overcomes the technical disadvantages of [110].
- The design and the implementation of 3D weight movements to express emotions.
- User feedback that tells us design guidelines and future research questions.

B.2 Related Works

Handheld devices with weight-shifting functions have been mainly explored in the virtual reality (VR) field. Since Woodruff and Helson [172] found the relationship between the presented torque and the human perception of heaviness in 1965, researchers have adopted this phenomenon to design weight-shifting devices [155, 175, 146, 139]. These works demonstrated that the virtual perception of objects can be well enhanced by changing the weight distribution. Compared to these previous works, the novelty of the present study stands in exploring the emotional expression capability of handheld devices by introducing 3D weight shifts. We also focus on giving the weight shift sensory during interaction with inanimate objects, such as a stuffed toy or a cushion, which are not pseudo-objects placed in a virtual area.

Emotion expression is a major topic in robotics research. Many social robots have been designed to convey emotional states using speech dialogues and non-verbal channels. For example, facial expressions [162], body movements [101], sounds [64], sweats [46], colors [159], vibrations [149], and their combinations [89, 149] have been explored as the expression modalities for social robots. Dynamic haptic parameters, such as the changes of skin temperature [123, 106, 14] and texture [61] and SwarmHaptics [77] have also been discussed in the literature. However, aside from [110], no study on robotics research has yet explored the usage of internal movement (i.e., weight shift) in emotion expression; thus, little knowledge is available for effective pattern design.

B.3 Hardware Design

This work aims to develop a 3D weight-shifting module, called OMOY-3D, which can be inserted to a variety of objects. We particularly focus on three different types of embodiments to which weight shifts are applied: a stuffed toy, a cushion, and a basket. OMOY-3D is fixed to the inside of each embodiment using the corresponding adjusters. This section describes the weight-shifting mechanism and the plug-in function of the OMOY-3D, detailing its fabrication and characteristics.

B.3.1 Weight-shifting Mechanism

Fig. B.3 illustrates the overall hardware specifications of OMOY-3D. Almost all parts were 3D printed using ABS or ASA materials. The exterior formed a regular sphere

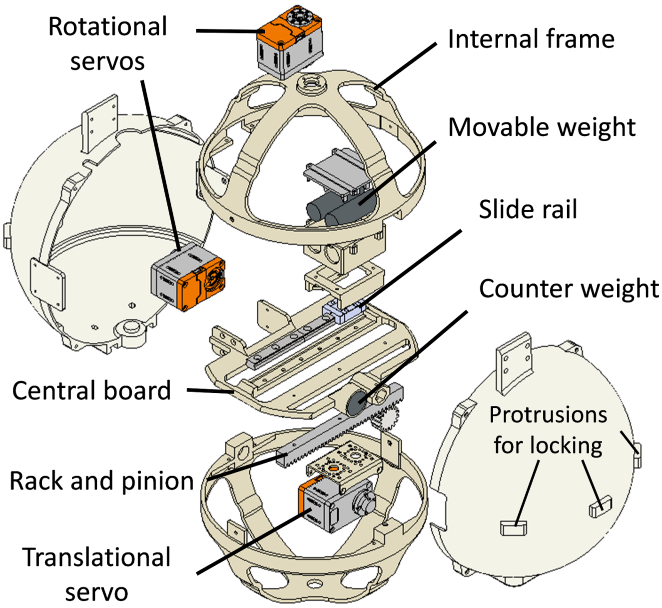

Fig. B.3 Hardware specification of OMOY-3D: 350 gram tungsten weight was attached to 1D translational and 2D rotational (vertical/horizontal) mechanism. This allows the weight to move spatially by following a 3D polar coordinate representation. 50 gram of weight was attached at the opposite side of the motor to compensate for horizontal motor mass.

with 188 mm diameter, while 350 gram of tungsten weight was implemented inside. The weight was attached to one translational and two rotational mechanisms, such that the weight can spatially move by following a 3D polar coordinate representation.

For the translation mechanism, we applied a pair of rack and pinion gear. The pinion gear was connected to a Dynamixel XC430-W150T servo motor (1.6 Nm at a 12 V with 1.4 A) and conveyed its torque to the rack. The rack was 130 mm long. The tungsten weight can be moved linearly for each gear pitch of 3.82 mm. A linear guide rail was inserted between the weight and a central board to smoothen the movement. The total weight of the part assembly moved by the translation mechanism was 479 gram.

For the rotation mechanisms, a Dynamixel XC430-W150T servo motor was installed to each vertical and horizontal axis. The motor in the vertical axis was fixed to the exterior of OMOY-3D and conveyed its torque to the internal frame, while that in the horizontal axis was fixed to the internal frame and conveyed its torque to the central board. Subsequently, 50 gram of weight was attached at the opposite side of the motor to compensate for horizontal motor mass.

B.3.2 Plug-in Function

A mechanical locking function was implemented to enable the module plug-in. Six protrusions were placed on the exterior of our prototype. Fixing was possible by matching them to certain channels of the adjuster. This section introduces how three different embodiments (i.e., stuffed toy, cushion, and basket) will be applied to OMOY-3D.

Installation to a Stuffed Toy

The stuffed toy (shown in Fig. B.2 left) is made of felt fabric. Its eyes and nose are represented by glossy black buttons. Inside the cap, there is a space for fixing a motor-controlling board. Theoretically, OMOY-3D can be applied to any commercially available stuffed toys with the right sizes. However, in this study, we fabricated it by ourselves to avoid copyright issues. For the installation, the protrusions on OMOY-3D surface were first inserted into the grooves of the adjuster. Next, OMOY-3D was rotated 30° inside the adjuster to lock and then installed to the stuffed toy. The size and the total weight, including OMOY-3D, were approximately H: 295 mm, W: 250 mm, D: 220 mm, 1866 gram, respectively.

Installation to a Cushion

The appearance of a cushion used in this study is shown in shown in Fig. B.2 center. We fabricated the adjuster using two boards of vinyl chloride resin and four pieces of 3D printed parts. The core unit was sandwiched with those parts and put into a commercially available cushion cover (45 cm × 45 cm). Four bags filled with small spheres made of styrene foam were inserted to give the sensory of softness to the users. The total weight, including OMOY-3D was approximately 2004 gram.

Installation to a Basket

The basket-style embodiment was designed for use as a vessel for popcorn usually bought in cinemas. It was made of thick papers with a unique pattern to fit this context. A 3D printed adjuster with a groove to lock the OMOY-3D was placed on the bottom of the basket. The embodiment measured H: 250 mm, W/D: 240 mm. The total weight was approximately 1533 gram.

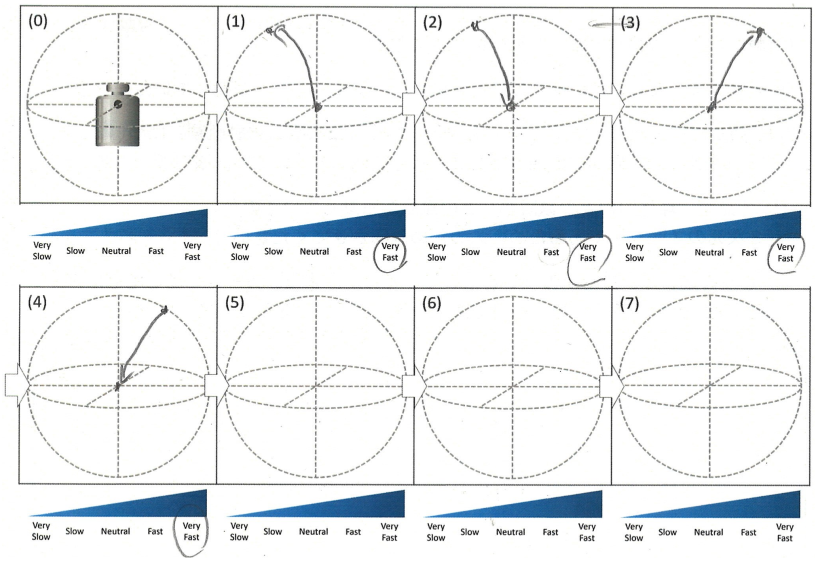

Fig. B.4 An example of draft ideas of 3D weight shift pattern drawn by a male participant in the sketch-drawing workshop. In his mind, this sketch represents his excited state the moment he saw the trailer of a video game. The weight was "jumping up," moving to the right/left and forward/backward of the sphere.

B.4 3D Weight Shifts Design

Several patterns have to be physically implemented to confirm the emotional expression capability of the 3D weight shifts. However, we needed to explore how emotions can be represented by the 3D weight shifts due to the lack of the design guidelines. In this work, we attempted to address this challenge in a three-step design process.

B.4.1 Sketch-drawing Workshop

We organized a workshop involving six student collaborators (three males and three females ages 21–25 years) to collect draft ideas for the 3D weight shift patterns.

At the beginning of the workshop, the collaborators were asked to remember recent events related to each of the following eight emotions: *excited, happy, relaxed, sleepy, bored, sad, annoyed, and afraid*[1]. They were then asked to draw the weight movements representing the emotions they remember. Fig. B.4 illustrates a sample sketch drawn by a participant. The gray-lined spheres indicate the area, in which the weight can move. Each blank was arranged in a time-sequential manner. Therefore,

[1]Those emotions were selected from Russel's Circumplex model of affect [136] and cover all four quadrants in this emotional model.

the collaborators drew important weight movements in each blank as if they were making a few-frame animation. For each frame, they were asked to choose a proper speed based on a five-point scale of 1: very slow to 5: very fast. Very slow (21 rpm) and very fast (105 rpm) translational weight movements were haptically presented to each collaborator using OMOY-3D to provide a reference in the physical sensation of weight shifts. In addition, we supplemented each sketch by asking the collaborators for a detailed explanation of the design concept and the geometric shape of each motion sketch.

B.4.2 Sketch Analysis

Through the workshop, 48 unique sketches (six collaborators, eight emotions) and the design concepts were collected. A qualitative analysis was performed to utilize the data collected from the workshop in designing the 3D weight shift patterns. In addition to the design concept, this analysis considered the movement features involved in each sketch. Each sketch was given codes describing its movement features based on the Laban-Movement Analysis (LMA) [82] and its Effort and Shape components. This section explains the coding procedure as a sketch analysis.

We define herein the *weight*, *space*, and *time* elements involved in the Effort component as "the average of speeds which were designated by the participants," "the shapes of trajectories mainly used in the sketch,", and "existence of sudden acceleration or deceleration in the speed design," respectively. We define the Shape component as "a region of the sphere mainly used in the sketch." The *horizontal*, *vertical*, and *sagittal* aspects of the sphere were considered. Aside from the LMA components, a repetition factor was also taken. This was known to have a relationship with the intentional movement design [152]. As a definition, the "existence of a pattern that is repeated around a certain point" was considered.

According to the definitions, we made a set of labels and the coding criteria for each of the abovementioned motion factors (Table B.1) while referring to the terms reported in [176]. Two coders, who provided the labels to the 48 sketches one by one while making a consensus on their judgments of each other, were assigned.

B.4.3 Pattern Implementations

We designed eight weight shift patterns representing certain emotions illustrated in Fig. B.5 based on the design concepts orally collected in the workshop and the codes added in the previous section. An OpenCR board was used to control the

Table B.1 Labels and the coding criteria toward the motion factors

	Label name	Coding criteria
Weight	Light	If the average speed is ≤2
	A little light	If the average speed is > 2, ≤ 3
	A little strong	If the average speed is > 3, ≤ 4
	Strong	If the average speed is > 4
Space	Direct	If straight paths are mainly used.
	Indirect (curve)	If curved paths are mainly used.
	Indirect (wave)	If waved paths are mainly used.
	Others	If it's difficult to classify into the above three.
Time	Sustained	If there is no speed change (constant).
	Intermediate	If there is a speed difference (< 3) between adjacent keyframes.
	Sudden	If there is a speed difference (≥ 3) between adjacent keyframes.
Horizontal	Spreading	If the weight moves to the left and right evenly.
	Enclosing	If there is no horizontal movement.
	Others (partial)	If the weight moves only to the left or right.
Vertical	Rising	If the weight moves mainly on the upper side of the sphere.
	Sinking	If the weight moves mainly on the bottom side of the sphere.
	Others (evenly)	If the weight moves to the up and down evenly.
	Others (none)	If there is no vertical movement.
Sagittal	Advancing	If the weight moves mainly on the front side of the sphere.
	Retreating	If the weight moves mainly on the back side of the sphere.
	Others (evenly)	If the weight moves back and forward evenly.
	Others (none)	If there is no sagittal movement.
Repetition	Repetitive	If there is repeated sequences.
	Single	If there is no repetition.

three Dynamixel motors that daisy chained and communicated with the board. We programmed eight weight shift patterns on this board.

Trajectory

Every dots plotted in Fig. B.5 denotes the positions where the weight reaches. In the *excited* and *happy* states, upper part of the sphere was used. Repetitions were included in these patterns, which the weight moved between the origin and each point. In *relaxed* state, the weight repeatedly moved on horizontal plane with a trajectory shown in Fig. B.5. For the *sleepy*, *bored*, and *sad*, the lower part of the sphere was used. For expressing *sleepy*, the weight moved such as head movements when a person is dozing. Consequently, a movement to express breathing was performed. In the *bored* state, the weight performed repetitive movements like a pendulum on

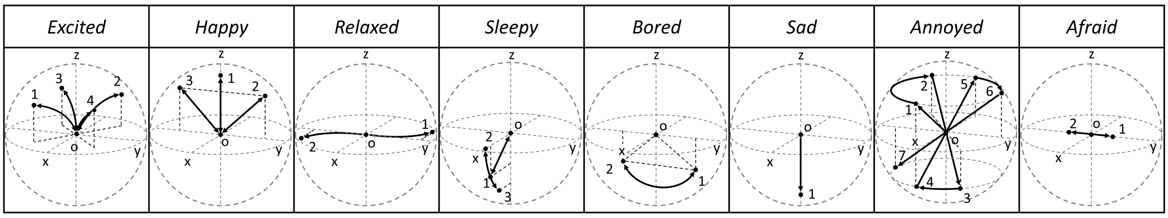

Fig. B.5 Trajectories of 3D weight shift patterns designed in this study.

a vertical plane (Y-Z plane in Fig. B.5). The weight vertically fell in the *sad* state. For expressing *annoyed*, the weight moved linearly on the diameter of the sphere while rotating in the range of ±45° to 90°. For the *afraid* state, vibration with a small amplitude was designed to express trembling.

Speed and acceleration

In the *excited*, *relaxed*, *sleepy*, *bored*, and *sad* states, we implemented a specific acceleration pattern to each motion design. For expressing *excited*, we designed a "skip" of the weight by using high initial velocity and gravitational acceleration. In the *relaxed* state, we implemented a motion sequence with a long deceleration section like the behavior of "rippling waves at a seacoast." For expressing *sleepy*, *bored*, and *sad* states, a slow and a gravitational acceleration were mainly considered. Each sinking section in these patterns was designed to be like "free-falls." For the other emotions (i.e., *happy*, *annoyed*, and *afraid*), motion sequences with specific accelerations were not included. The weight moved at a constant speed, either fast or very fast for these emotions. Here, as an example, Fig. B.6 shows a speed and acceleration design of the weight shift patterns that represents (a) *relaxed* and (b) *afraid*.

B.5 User Test

User tests were carried out, which aimed to check the feasibility of the implemented weight-shifting patterns with different embodiments. Three different interaction scenarios were set, and the weight shifts were presented during the interactions. Five participants (three males and two females aged 18–26 years) were recruited[2] in this study, and each experienced the three settings one by one. An experimenter

[2]The study protocol was approved by the research ethics committee of the Faculty of Engineering, Information, and Systems in University of Tsukuba. All participants provided informed consent.

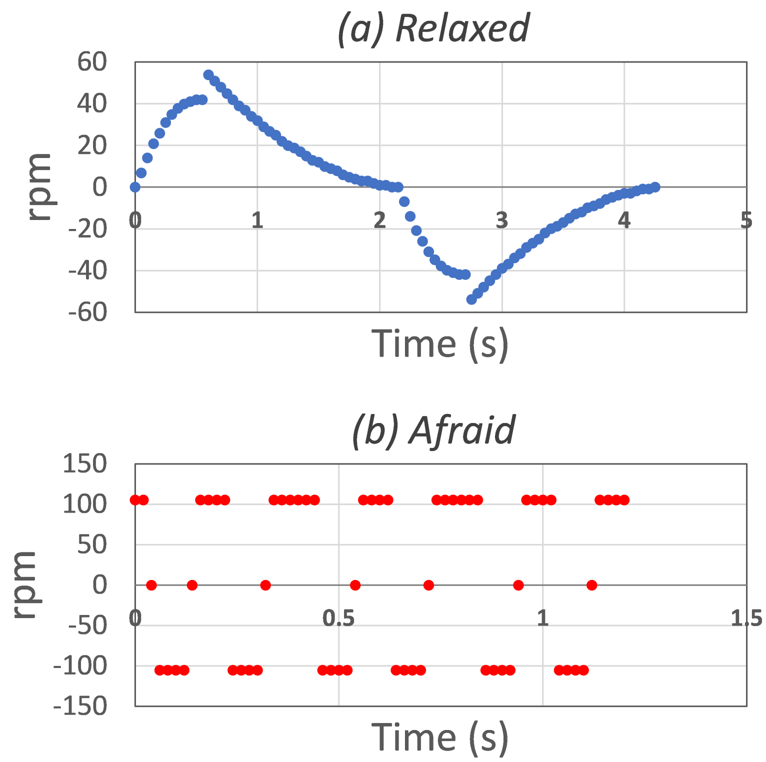

Fig. B.6 Speed and acceleration designs of the weight shifts for expressing (a) relaxed and (b) afraid. Each point indicates the RPM value read by the translational servo.

sat in front of the participants and collected user feedback through semi-structured interviews in each setting. All experimental procedures were videotaped and used in the analysis.

B.5.1 Interaction with a Stuffed Toy-style Robot

Scenario and materials

The stuffed toy-style embodiment and all eight weight shift patterns were used. We introduce herein a scenario to the participants, in which "a stuffed toy-style robot reads out a text message received from a friend" by using its voice synthesis function. Mediating human messaging is a possible application of social robots [113]. The emotional elements of messages might be enhanced, if the weight-shifting function is added to the robot.

Before performing this study, we created a set of daily text messages for use with the weight shifts. First, we made multiple text messages as candidates based on the discussion with the workshop participants. At least two candidates were made for each emotion. We then conducted an online survey with seven participants, who are different from the participants in the user test, to select the one which can be easily associated with each emotion. For each candidate, the participants were asked "According to the sentence, which is the closest to the emotion that the sender is trying to convey?" The question had eight forced-choice options (excited/happy/relaxed/sleepy/bored/sad/annoyed/afraid). As a result, text messages having the highest agreements among the emotion perception of the participants were determined. Accordingly, we created audio clips that are used for the robot speech using these texts. A text-to-speech API provided by NTT Docomo was used for the voice synthesis[3].

Procedure

Only the speech factor of the robot was investigated in the first half of this setting. The participants were asked to hold the robot. The audio clip was played using a small speaker attached inside its body. For each audio clip, the participants were asked to evaluate whether the robot's voice was suitable to convey emotional content of the message. A five-point scale of "1: not suitable" to "5: suitable" was used in answering it.

We investigated the speech and weight shift combinations in the second half of this setting. The participants were asked to hold the robot again. The robot then read the message while presenting the corresponding weight shift pattern. For each robot expression (speech + weight shift), the participants were asked to evaluate its suitability based on the five-point scale. In addition, for each expression, the participants were asked in an open-ended question to describe their impression on the presented weight shift, detailing what feature caused that impression.

User feedback and discussion

Fig. B.7 shows the average of the perceived suitability for each emotion expression. Overall, the participants perceived high suitability to the robot that presents weight shifts when it reports messages. The average of the perceived suitability for each expression was higher than 3. Because large differences were observed in speech only vs. speech + weight shifts comparison in the *relaxed*, *sleepy*, *sad*, *annoyed*, and *afraid* states, using of the weight shifts might improve the human perception of

[3]The robot spoke with a neutral speed, pitch, and emotion.

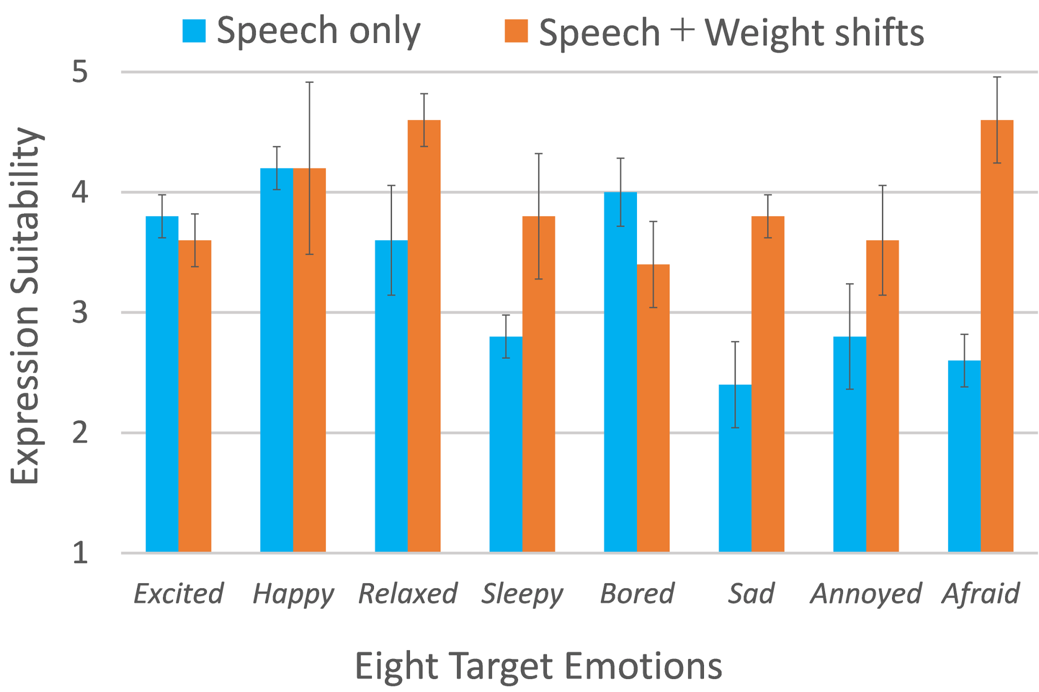

Fig. B.7 Perceived suitability for each emotion expression (speech only or speech + weight shift) during the interaction with a stuffed toy-style robot. Error bars are 1 SEM.

suitability for the robot speech. Therefore, in this scenario, the created 3D weight shift patterns might be effective for expressing those emotions.

However, the positive effects of the weight shifts were not found in the *bored* state. For this emotion expression, two participants scored the suitability as 2 and 3. One of those participants mentioned that: "Although the speed design was good, it moved too much. That is, for expressing *bored*, the weight movement should be smaller." Thus, it might be important to design the length of the trajectories shorter or reduce the number of motors to be activated to improve the *bored* expression.

On the other hand, for the *excited* and *happy* state, we could not see big differences in the suitability perceptions mainly because the voice used herein might be fit to the topic of these messages (a female-like voice was used for the robot speech). Three participants actually reported that the robot voice was high, and that was actually good for expressing positive emotions.

A further research question arose here considering the interaction effects between the voice and weight shifts: How will the human perceptions of the emotions be affected by the combinations of the voice types of the robot and the weight shift patterns? Previously, HRI researchers reported that the combination of haptics and other expression modality might have a unique effect on the user's perception of emotions. For instance, [123] reported that in haptic interactions with social robots, there are combinations where the temperature expression predominates over the facial expression when judging the robot's emotional state. Therefore, exploring this research question will particularly contribute to a weight shift pattern design used when the message content does not match the emotional state of the sender.

B.5.2 Interaction with a Cushion-style Robot

Scenario and procedure

The cushion-style embodiment and the weight shift pattern representing *relaxed* were used. We introduced a scenario to the participants, in which "they are trying to get relaxed with a cushion during a break."

The cushion presented the weight shift while being embraced by the participants. In this setting, the participants' opinions on the following questions were gathered through semi-structured interviews: "Frankly speaking, what did you think of the weight movement?", "Do you think is it possible to get relaxed by the presented weight movement?", and "What feature do you think needs to be improved to make you more relaxed?"

User feedback and discussion

Two participants mentioned that they thought it was possible to relax using the cushion robot with weight shifts. On the contrary, the other three participants were skeptical on this effect. However, most of their comments suggested that the exhibiting weight shifts could increase or continue their motivations to hold the cushion. For instance, a participant commented that "I think this cushion can be held for a long time. For example, I often use cushions when I'm lonely, but this cushion robot gives me a sense as if it is living and makes me want to use it more than those." Thus, we conclude that applying OMOY-3D to the cushion-style embodiment is feasible, and further investigation is needed on the effect of the interaction durations with the cushion robot on user stress reduction.

B.5.3 Interaction with a Basket-style Robot

Scenario and procedure

The basket-style embodiment and the weight shift pattern representing *afraid* were used. In this setting, we introduced a scenario to the participants, in which "they are watching a movie while eating popcorn."

With this setting, the participants were then asked to watch a horror movie clip for approximately 7 min while holding the basket. During the movie, the experimenter sent a command to the robot to exhibit the weight shifts in predefined moments (e.g., the title of the movie appeared or a hero in the movie found a ghost). The weight shift was presented to each participant four times. After the video watching, the participants were then interviewed about their opinions to the following questions: "Frankly speaking, what did you think of the weight movement?", "Do you think is it possible to enhance the watching movie experiences by the presented weight movements?", and "What feature do you think needs to be improved to make the experience better?"

User feedback and discussion

Through the interview, four of the five participants reported that the robot and its weight shifts contributed to enhancement of their movie watching experience. They expressed the following comments: "it aroused my disquieting feeling," "it brought out surprises and enhanced," and "it was fun as if I was watching a 4DX movie." These comments suggested that the weight shift pattern used in this scenario might be feasible. However, one participant had a totally negative opinion on the setting because a slight but certain preliminary motion of the weight shifts bothered his concentrations to the movie. This feedback indicates that it is important to design the speed and acceleration of the preliminary motions smaller, thus avoiding the distractions of the users.

B.6 Limitations and Future Work

There are limitations that suggest a need for further improvements. The current OMOY-3D wires (connected to the three Dynamixel motors) obstructs continuous rotations along the vertical and horizontal axes. The rotation angles of all created weight shift patterns were designed between 0° to 360°. Fully wireless designs were needed to enable the implementation of more patterns than the current state.

Multiple participants mentioned that motor sounds were a little distracting. Servo noises, particularly in the patterns expressing *annoyed*, were also pointed out. However, interestingly, for a servo noise at the pattern for expressing *relaxed*, some participants mentioned that the noise was comfortable (i.e., recognized as sounds like waves at the seacoast). Therefore, investigating the effect of servo noises would be an interesting topic in the future work.

Follow-up studies are necessary to confirm the scalability of our user test and to strengthen the findings. Particularly, empirical studies with a larger number of participants are needed.

Appendix C

List of Publications

Journal Articles

1. Yohei Noguchi, Hiroko Kamide, and Fumihide Tanaka. Weight Shift Movements of a Social Mediator Robot Make It Being Recognized as Serious and Suppress Anger, Revenge and Avoidance Motivation of the User. Frontiers in Robotics and AI (accepted).

2. Yohei Noguchi, Hiroko Kamide, and Fumihide Tanaka. Personality Traits for a Social Mediator Robot Encouraging Elderly Self-Disclosure on Loss Experiences, ACM Transactions on Human-Robot Interaction, Vol.9(3), pp.1-24, 2020.

3. 野口 洋平, 上出 寛子, 田中 文英. 遠隔コミュニケーションを仲介するロボットが高齢話者の自己開示に与える影響. ヒューマンインタフェース学会論文誌, Vol.20 (1), pp.67-78, 2018.

Refereed Conference Papers

1. Yohei Noguchi and Fumihide Tanaka. OMOY: A Handheld Robotic Gadget that Shifts its Weight to Express Emotions and Intentions. Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI 2020), Paper No.646, pp.1-13, Honolulu, USA, 2020.

2. Yohei Noguchi, Hiroko Kamide, and Fumihide Tanaka. Effects on the Self-Disclosure of Elderly People by Using a Robot Which Intermediates Remote Communication. Proceedings of the 27th IEEE International Symposium

on Robot and Human Interactive Communication (IEEE RO-MAN 2018), pp.612-617, Nanjing, China, 2018.

3. Yohei Noguchi and Fumihide Tanaka. A Pilot Study Investigating Self-Disclosure by Elderly Participants in Agent-Mediated Communication. Proceedings of the 26th IEEE International Symposium on Robot and Human Interactive Communication (IEEE RO-MAN 2017), pp.29-34, Lisbon, Portugal, 2017.

4. Yohei Noguchi and Fumihide Tanaka. A Shared-Agent System for Encouraging Remote Communication over Three Generations: The First Prototype. Proceedings of the Companion of the 2017 ACM/IEEE International Conference on Human-Robot Interaction (ACM/IEEE HRI 2017), pp.229-230, Vienna, Austria, 2017 (Late breaking report).

Other Presentations

1. Yohei Noguchi and Fumihide Tanaka. Demonstration of OMOY: A Handheld Robotic Gadget that Communicates with Humans by Using Weight Shifts. Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems, pp.1-4, Honolulu, USA, 2020（Interactivity demo track).

2. 野口 洋平, 田中 文英. 体重移動により感情や意図を表出するハンドヘルド型コミュニケーションロボットOMOY. 第34回人工知能学会全国大会, 2P4-GS-11-04, 熊本, 2020.

3. 野口 洋平, 上出 寛子, 田中 文英. 家族の世代間コミュニケーションを支援する仲介者エージェントの研究. 第32回人工知能学会全国大会, 4J1-01 鹿児島, 2018.

4. 野口 洋平, 田中 文英. ロボットを介した遠隔コミュニケーションにおける高齢者の自己開示の調査. 第31回人工知能学会全国大会, 3F1-OS-03a-2, 名古屋, 2017.

5. 野口 洋平, 田中 文英. 多世代間コミュニケーション促進のためのシェアエージェントシステムの開発. 第17回計測自動制御学会システムインテグレーション部門講演会, 2O2-1, 札幌, 2016.