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Effect of Robot's Listening Attitude Change on Self-disclosure of the Elderly

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Abstract
Self-disclosure of life experiences from the viewpoint of integrity is considered beneficial to the psychological health of older adults. It has been shown that people tend to self-disclose more to people they like. Compared to a consistent invariant reward, an improvement in the rewarding behavior of a person has been shown to have a greater positive impact on an individual's liking for the person. Based on these previous studies, we explored the psychological impact of self-disclosure of integrated life experiences on the elderly and the effect of the change in the robot's listening attitude on the elderly's self-disclosure. We conducted an experiment in which 38 elderly participants were asked to self-disclose their life experiences to a robot for approximately 20 min. The participants interacted with either a robot with a consistently positive listening attitude or a robot that initially had a neutral listening attitude that changed to a positive listening attitude. The results showed that self-disclosure of integrated life experiences to the robot had a psychological impact on improving self-esteem. In addition, changes in the robot's listening attitude were found to promote self-disclosure and enhance its impact on self-esteem.

Keywords Human–robot communication · Interaction design · Self-disclosure · Elderly care · Self-esteem

1 Introduction

With an increase in the elderly population in recent years [1], the importance of health promotion for the elderly has increased [2].

Self-disclosure, defined as the behavior of communicating information about oneself to a specific other person through language [3], is considered important for the older adults' health. Jourard [4], a pioneer in the study of self-disclosure, argued that the ability to allow an authentic self to be known to at least one significant other is a prerequisite for a healthy personality [4]. The positive relationship between self-disclosure and psychological health has been demonstrated in several previous studies [5,6]. For example, it was revealed that disclosure is associated with lower stress levels [7], and less self-disclosure is associated with neuroticism [8].

"Self-disclosure of integrated life experiences," especially, which refers to looking back on one's life from an integrative perspective and sharing acquired memories and values [9,10], is considered helpful for the elderly. For older adults, talking about their past has positive psychological impacts such as improved generativity [11] and self-esteem [12–14].

However, opportunities for self-disclosure among older adults appear to on the decrease. One of the reasons for this is the increasing number of elderly people living alone [15]. In addition, the spread of the COVID-19 is thought to restrict their ability to go out, thus reducing their opportunities to communicate with others [16].

Communication robots have attracted attention in recent years as conversation partners for the elderly [17]. Previous studies have revealed that people self-disclose to communication robots, as well as they do to humans. Whether the listener is a human or robot, the actual amount of self-disclosure did not differ [18]. In fact, robots were preferred to humans for self-disclosure of negative emotional topics [19].

A few researchers have investigated how robot behavior can elicit more self-disclosure from the elderly. Elderly peo-

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ple were found to be more likely to self-disclose to robots that were designed to listen rather than speak [20], and robots with expressive social behaviors such as greetings [10].

Changes in the robots' listening attitudes may induce greater self-disclosure. Compared with consistent invariant reward, an improvement in the rewarding behavior of a person has a greater positive impact on an individual's liking for the person; this is called "gain effect" [21]. Furthermore, it has been reported that in person-to-person communication, people are more likely to self-disclose to people they are fond of [22]. Therefore, an improvement in the robot's listening attitude may enhance the elder's liking for the robot, which may induce greater self-disclosure.

Thus, communication robots can replace people as recipients of the self-disclosure of the life experiences of the elderly. Furthermore, a change in the robot's listening attitude may increase the elderly's liking for the robot and improve their self-disclosure. However, the effects of a change in the robot's listening attitude on the elderly's liking for the robot, as well as on self-disclosure, have not been studied thus far.

We first performed a preliminary experiment to examine the effect of the change in listening attitude [23]. We observed that elderly individuals were more likely to self-disclose to robots with improved attitudes. Therefore, the purpose of this study was to clarify the psychological impact of self-disclosure of integrated life experiences on the elderly and the effect of the change in the robot's listening attitude on the elderly's self-disclosure using a larger sample.

2 Related Research

2.1 Self-disclosure in Human–Human Interaction

Self-disclosure, defined as the behavior of communicating information about oneself to another person through language [3], is considered essential for the elderly. Suganuma [24] studied the importance of self-disclosure in old age, referring to the dilemma of "integrity" versus "despair" in the final stage of Erikson's stage theory of psychosocial development [25]. "Integrity" is "a sense of satisfaction in having lived a good life and the ability to approach death with equanimity" [26]. "Despair" is "a feeling of bitterness about opportunities missed and time wasted, and a dread of approaching death" [26]. In [24], it was suggested that an elderly's self-disclosure, i.e., talking to others about their confusion about loss and experiences from an integrative perspective, plays an important role as the elderly attempts to cope with "despair" and achieve "integrity."

Suganuma [24] also found that self-disclosure in old age can be categorized into three types of experience they center on, namely, everyday, integrated life, and loss experiences. The "self-disclosure of everyday experiences"is the sharing of feelings that the elderly generally experiences on a daily basis, such as recent enjoyment. The "self-disclosure of integrated life experiences" entails looking back at one's life from an integrative perspective and sharing the acquired memories and values such as beliefs acquired through life experiences. The "self-disclosure of loss experiences," entails sharing worries about the present and future such as health concerns.

Researchers have examined the effect of "self-disclosure of integrated life experiences" on older adult's Erikson's stage of psychosocial development. Tabuchi and Miura revealed that the older adults' "generativity" increased after they talked to younger adults about experiences from their youth and the wisdom they had gained [11]. Generativity is defined as "the concern for establishing and guiding the next generation" [27] and is the positive goal of middle adulthood in the seventh stage of Erikson's stages of psychosocial development [25,28]. In recent years, with changes in social trends, such as longer life expectancy, it has been pointed out that generativity is an important developmental issue not only in middle age, but also in older age [29].

Moreover, life review, a process in which older adults reflect upon and analyze life experiences [30], is known to affect life satisfaction, psychological well-being [31], and self-esteem [12–14]. It has been suggested that the achievement of "integrity," which is the positive goal of old adulthood in the eighth stage of Erikson's stage theory, increases self-esteem [32].

In addition, self-disclosure has been shown to be related to liking. A laboratory experiment found that the amount of personal self-disclosure increased with highly favored partners [6]. Altman and Taylor [33] proposed the "social penetration theory," which predicts that the "breadth" and "depth" of reciprocally exchanged self-disclosure increases as the relationship between the two parties progresses from initial acquaintance to intimacy.

2.2 Self-disclosure to Communication Robots

Previous studies have demonstrated that people disclose information to communication robots. For women, there was no difference in their willingness to self-disclose and the amount of actual disclosure, regardless of whether the listeners were robots or humans [18]. Furthermore, it has been reported that robots are preferred over humans for negative and emotional topics [19]. Bethel et al. [34] interviewed school students about their experience of bullying using robots. The results revealed that the children talked more about being bullied over their appearance to the robots than to humans. It has also been shown that there is no difference in the extent of people's actual disclosure to humans and robots on non-neurotic topics such as school performance and issues related to daily life [35]. A recent study attempted

to use robots to conduct medical interviews because people tend to be more honest when disclosing health-related information to robots [36]. Ueda and Takahashi [37] compared robots and humans as listeners in the life reviews, as introduced in Sect. 2.1. Qualitative analysis of the conversations confirmed that the elderly tended to talk more about universally transmissive values with robots than with humans. The authors of [37] concluded that robots can potentially provide elderly patients with greater safety and comfort in conveying their unique life narratives.

Several studies have been conducted on the robot design that can elicit self-disclosure. Kumazaki et al. [38] compared robots with different visual appearance. The results showed that children with autism spectrum disorder disclosed more to the visually simple robot than to the android robot when talking about their most embarrassing moments. In addition, Barfield [39] found through a questionnaire survey that a child-like friendly appearing robot, which wasjudged to display relatively high affect, was preferred over an android and a less-empathetic-appearing robot as a self-disclosure partner. A possible reason for this preference is that the child-like friendly appearance was perceived as non-judgmental toward self-disclosure.

Some studies have focused on robot behavior. Shiomi et al. [40] investigated whether physical contact with robots facilitated self-disclosure in humans. The results showed that a reciprocated hug behavior, in which the robot sometimes patted participants on the back during the interaction, encouraged self-disclosure. Martelo et al. [41] found that the self-disclosure of people improved when the expressivity of the robots increased through facial expressions and arm movements. Noguchi et al. [10] found that robots with social behaviors improved self-disclosure in the elderly. In [10], older adults' ease of self-disclosure to their family was compared in three types of communication mediators: (1) a telephone, (2) a robot that did not move and only beeped, and (3) a socially expressive robot that responded verbally and greeted the elderly. The results showed that the elderly felt it was easier to self-disclose when using the socially expressive robot than when using the non-expressive robot or the telephone.

One study successfully elicited self-disclosure by focusing on their attitudes toward communication [20]. Hirano et al. [20] found that a robot designed primarily for listening rather than speaking elicited self-disclosure in elderly people. The study in [20] considered a "speaking robot" that actively responded to the elder's speech with opinions and advice and a "listening robot" that responded to the elder's speech using not only language but also ambiguous humming. Compared with the elderly who interacted with the "speaking robot," those who interacted with the "listening robot" uttered more open communication content, which included self-disclosure-related utterances.

The effects of self-disclosure to robots on humans have been extensively researched. Burger et al. [42] found the number of self-disclosures to a robot affected the perceived relatedness of children to the robot. In an experiment, children were asked to communicate with a robot continuously for approximately two weeks at home. The robot also performed self-disclosure to elicit reciprocal self-disclosure from the children. It was found that children who responded more to the robot's self-disclosure found the robot more relatable. The effects of robot self-disclosure on human emotions have been explored in recent studies. Akiyoshi et al. [43] conducted an experiment in which participants disclosed their recent problems to a robot and found that a robot with a conversational system that elicits human self-disclosure assuages anger. In addition, through experiments, Duan et al. [44] found that self-disclosure to a robot is effective in alleviating negative emotions. In this study, it was confirmed that among the participants who felt strongly negative after being exposed to shocking video footage, the emotions of those who talked to the robot after watching the video changed more positively, compared to those who wrote down their feelings. Based on this result, it was concluded that those who are sad and alone desire to talk to somebody and that robots can be used as listeners for people who tend to feel lonesome and may want to self-disclose, such as the elderly.

2.3 Gain Effect

Aronson and Linder [21] hypothesized that the sequence of a person's behavior toward a counterpart has a more significant impact on the counterpart's liking for the person than on the total number of rewarding acts. Through laboratory experiments, the authors of [21] revealed the existence of a "gain effect," in which people like a person who initially has a negative attitude but gradually develops a positive attitude more than person who consistently has a positive attitude, and a "loss effect," whereby people disfavor a person who initially has a positive attitude but gradually develops a negative attitude more than a person who consistently has a negative attitude. The "gain and loss effects" were proven to affect opinion change in communicating partners [45].

Moon and Nass [46] revealed the existence of the "gain and loss effects" in human-computer interactions. Moreover, Komatsu and Yokoyama [47] experimented to determine whether the "gain and loss effects" could be applied to human interaction with AIBO. In the experiment shown in [47], AIBO was endued with two behaviors: (+) friendly behavior, in which it responded to the user's speech by wagging its tail, and (−) bad behavior, in which it responded to the user's speech by shaking its head and barking. There were four conditions: (1) positive, (2) negative, (3) gain, and (4) loss. In (1) the positive condition, AIBO consistently behaved in a friendly manner, namely, (+ +). In (2) the negative condition,

AIBO consistently displayed bad behavior, namely, (− −). In (3) the gain condition, AIBO behaved poorly in the first half of the interaction and was friendly in the second half of the interaction, namely (− +). In 4) the loss condition, AIBO behaved poorly in the first half of the interaction and poorly in the second half of the interaction, namely (+ −). There was no statistically significant difference in users' impressions of AIBO across the conditions. The authors of [47] conjectured that AIBO only responded to the participants' verbal commands. Hence, there were no significant difference across the conditions because the interaction between the participants and AIBO was unilateral. They also suggested that bilateral interactions were crucial to confirm the gain and loss effects in human and robot interactions.

Tainaka et al. [48] implemented attitude changes in 3D virtual avatars for user behavior modification. The authors of [48] defined "time-dependent TSUNDERE" whereby the performer is initially cold (TSUN) to the beholder, but gradually changes to a state of kindness (DERE) toward the beholder after an event.

Our preliminary study [23] revealed that robots whose listening attitudes changed from neutral to positive elicited more self-disclosure from the elderly than robots whose listening attitudes were consistently neutral or positive.

However, three points were not clear in that study. First, does self-disclosure of integrated life experiences to robots have a positive psychological impact on the elderly? Second, does the change in the robot's listening attitude increase the elderly's liking for the robot, as in the gain-effect studies with humans? [21]; Third, is the positive psychological impact, if it exists, strengthened by a change in the robot's listening attitude? In this study, we examined these points against the backdrop of previous studies.

3 Hypothesis

Previous studies have revealed that elderly people's generativity and self-esteem, which are the positive goals of Erikson's stage theory of psychosocial development [25], are improved by reflecting on and disclosing past experiences [11–14]. This was referred to as "self-disclosure of integrated life experience" in [24]. In addition, people treat robots as communication partners and self-disclose to them, as they would humans [18,19,34,35]. Thus, we propose the following hypotheses:

H1-a Self-disclosure of integrated life experiences to robots improves generativity in the elderly.

H1-b Self-disclosure of integrated life experiences to robots improves self-esteem in the elderly.

Additionally, "gain effect," whereby "people like a person who initially has a negative attitude but gradually develops a positive attitude more than a person who consistently has a positive attitude" [21], has been identified in human–human interaction. "Gain effect" has also identified in human-computer interaction [46]. People self-disclose more to people they like [6]. Therefore, we propose the following two hypotheses.

H2-a Compared with robots with consistently positive listening attitudes, robots with positively changing listening attitudes are more liked by elderly people.

H2-b Compared with robots with consistently positive listening attitudes, robots with positively changing listening attitudes elicit more self-disclosure by elderly people.

As indicated in H2-b, it can be expected that the elderly will self-disclose more to robots with positively changing listening attitudes than to robots with consistently positive listening attitudes. Therefore, compared to the robot with the consistently positive listening attitude, the robot whose listening attitude changes positively may improve the generativity and self-esteem of the elderly by eliciting greater self-disclosure of their life experiences. Thus, H3-a and H3-b were derived.

H3-a The generativity of the elderly who self-disclose to a robot with a positively changing attitude improved more than that of those who self-disclose to a robot with a consistently positive listening attitude.

H3-b The self-esteem of the elderly who self-disclose to a robot with a positively changing attitude improved more than that of those who self-disclose to a robot with a consistently positive listening attitude.

4 Method

4.1 Overview

An experiment was conducted with 38 participants. They participated in the experiment one at a time and experienced two self-disclosure sessions with a robot. In the first session, the participants were asked to self-disclose their everyday experiences (hereinafter called the "everyday experiences session"). In the next self-disclosure session, they were asked to self-disclose their integrated life experiences (hereinafter called the "integrated life experiences session"). Each session lasted for a maximum of 10 min, which was determined based on previous studies on gain effects [21] and self-disclosure to the robot [10,40]. The participants evaluated their impressions of the robot, generativity, and self-esteem at three time points: before self-disclosure (hereinafter called the "pre-

experiment questionnaire"), after the everyday experiences session (hereinafter called the "between-sessions questionnaire"), and after the integrated life experiences session (hereinafter called the "post-experiment questionnaire"). In addition, they were asked to rate their willingness to self-disclose to the robot after the integrated life experiences session. They were also interviewed for approximately 15 min, during which all their utterances were recorded.

The factor in this experiment was the type of listening attitude of the robot (hereinafter called *robot's listening attitude* factor). This factor was a between-participants factor with two levels: "consistently positive" (CP) and "change" (Ch). In the "CP level, the robot responded positively to the disclosure of participants in both the "everyday experiences session" and "integrated life experiences session." At the Ch level, the robot behaved neutrally in the "everyday experiences session" but acted positively in the "integrated life experiences session."

In a preliminary experiment [23], we also set the "consistently neutral" (CN) level, where the robot behaved neutrally as the participants self-disclosed in both the "everyday experiences session" and "integrated life experiences session." The results indicated a marginal difference between the willingness to self-disclose to the CN and Ch level robots (CN level < Ch level). Therefore, we did not consider the CN level in this study because our final goal was to design a robot that would elicit more self-disclosure from the elderly.

This study was approved by the Tokyo Institute of Technology's Human Subjects Research Ethics Review Committee (2021023).

4.2 Experimental Setup

The experiment setup is shown in Figs. 1 and 2. Two sets of desks and chairs were provided for each participant. One set was used when responding to the questionnaire, and the other was used when the participant self-disclosed to the robot. The experimenter operated the robot at the desk and chair, which were placed out of sight of the participants using partitions.

4.3 Participants

A total of 38 (16 male and 22 female) Japanese volunteers aged 61–90 years (M = 76.3, SD = 6.40) participated in the study. They were randomly divided into two groups of 19 each, considering gender and age balance. The CP group participants interacted with the robot at the "consistently positive" level and Ch group participants interacted with the robot at the "change" level. All the participants lived independently in their homes.

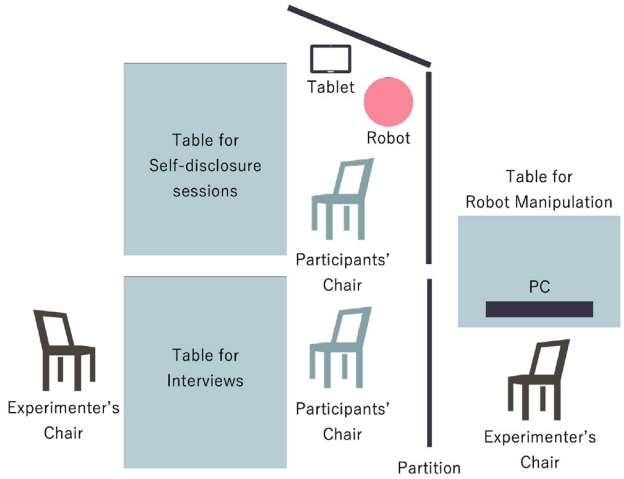

Fig. 1 Experiment setup. Participant used one table for questionnaire and interview and another for interaction (self-disclosure) with the robot

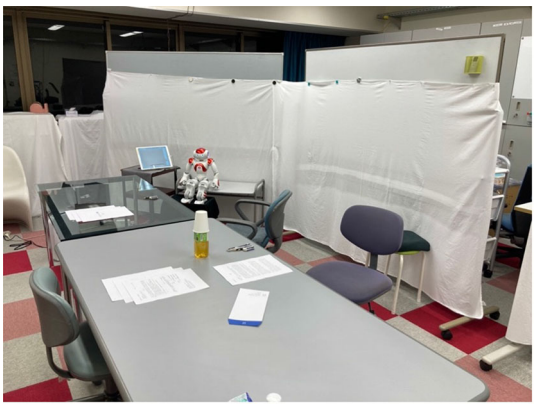

Fig. 2 Experiment setup (photo). The table in the foreground was for questionnaire and interview, and the one in the background was for interaction with the robot

4.4 Robotic Apparatus

The robotic platform used in our experiment was NAO [49], and all the behaviors were implemented using a Choregraphe development environment [50]. We controlled the robot remotely using the Wizard of Oz method [51].

In a preliminary experiment [23], we used Pepper [52]. However, the use of Pepper could result in bias, as the participants were familiar with Pepper from their interactions in daily life. Therefore, we used the NAO, which is not commercially available, to prevent participant bias from affecting the results of the experiment.

4.5 Robot Behavior

The robot's neutral and positive listening behavior was implemented based on the study by Tabuchi and Miura [53], who examined whether differences in young people's responses

to the narratives of the elderly affected their post-narrative generativity. In our study, there were five main differences: verbal response, back channeling, gaze, gesture, and posture. Each of these is explained as follows: *Verbal response* In [53], a positive verbal response was described as "agreeing with the content and emotion of the other person's conversation" (p. 254). Therefore, the robot with positive listening behavior produced utterances that agreed with the six basic emotions: anger, disgust, fear, joy, sadness, and surprise [54], for example, "That must have made you angry." and "That must have been disgusting." The robot with the neutral listening behavior did not use these utterances. We also implemented a complementary utterance in a robot with a positive listening behavior. Dai et al. [55] found that people liked others who gave complements to their self-disclosure more than they did those who responded neutrally. For example, the robot with positive listening behavior said "That's really nice." or "That's really great." In contrast, the robot with neutral listening behavior responded to the participants' self-disclosure by saying just "I see." or "Okay." *Back-channeling* In [53], one of the aspects of positive response behavior was described as "encouraging conversation with a positive back-channeling" (p. 254). Therefore, we implemented "huh" as a response of the robot with positive listening behavior and used it at appropriate times during the participants' self-disclosure. The robot with neutral listening behavior listened to the participants' self-disclosure without back channeling. *Gaze* In [53], one of the aspects of positive response behavior was described as "turning one's gaze when the content of the conversation is positive" (p. 254). In a study of the effect of gaze patterns during conversation on the evaluation of impressions of conversation confederates, Argyle et al. [56] found that people preferred confederates to continuously look at them rather than not looking at them. Therefore, the robot with positive listening behavior was designed to maintain eye contact with the participants. The robot with neutral listening behavior was designed to avoid eye contact with the participants. *Gesture* In [53], one of the aspects of the positive response behavior was described as the "frequent use of nodding that facilitates conversation in response to the other person's conversation" (p. 254). Therefore, for the robot with the positive listening behavior, we implemented a vertical neck movement and used it at appropriate times during the participants' speech along with the "huh" utterance. However, the robot with the neutral listening behavior did not nod in similar instances. *Posture* In [53], one aspect of the positive response behavior was described as "leaning forward in response to the content of the conversation" (p. 254). In a study on the impact of therapists' nonverbal behavior on psychotherapy patients, Dowell and Berman [57] found that therapists were rated as more empathetic when they leaned toward the patient. Therefore, a robot with positive listening behavior was designed to lean forward toward the participants. In contrast, we designed the robot with a neutral listening behavior to maintain an upright posture.

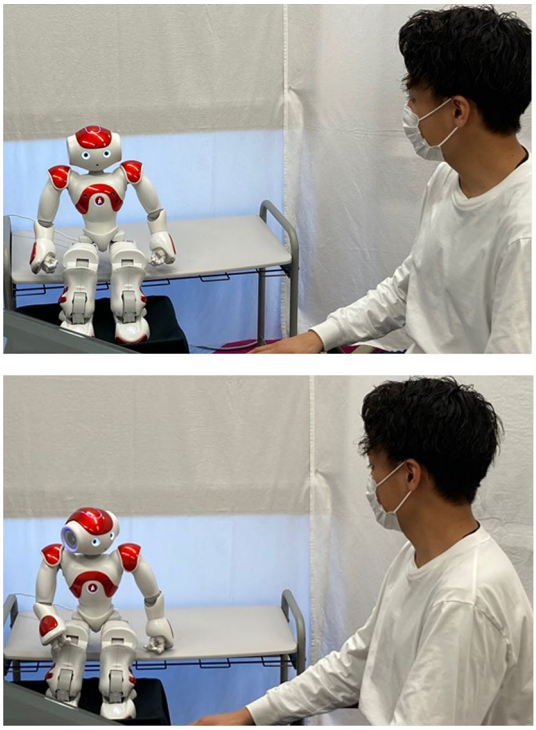

Fig. 3 Robot with neutral listening behavior (upper) and robot with positive listening behavior (bottom). The person in the photos is the authors' colleague and not a real participant

Robots with the neutral listening behavior and positive listening behavior are shown in Fig. 3.

4.6 Self-disclosure Sessions

In this experiment, there were two self-disclosure sessions: an "everyday experiences session" and "integrated life experiences session." Although self-disclosure of integrated life experiences alone would suffice to test our hypotheses, we conducted the "everyday experiences session" session before "integrated life experiences session" for two reasons. First, at least two sessions are required to implement the Ch level. Second, the content of self-disclosure between two parties is known to gradually deepen [33]. We considered it difficult for the participants to abruptly self-disclose their integrated life experience to the robot. Integrated life experiences include personal values, which comprise the intermediate layer content (the second-most intimate self-disclosure content) [33]. Therefore, we conducted the "everyday experiences session," where participants talked about the peripheral layer content (the lowest intimate self-disclosure content). The topics were based on Suganuma's [24] self-disclosure topics of everyday experiences and the low intimate-level self-disclosure topics in a previous research [58]. In the "everyday experiences ses-

sion," the robot posed 10 questions on selected topics such as the participants' hometown, hobbies, and recent enjoyment.

We also implemented a self-disclosure utterance from the robot regarding the content of the question before asking it in the "everyday experiences session." The reason for introducing the robot's self-disclosure was that studies have shown that mutual self-disclosure elicited deeper self-disclosure from the participants in the human-computer interaction field [59] and human-virtual agent interaction field [58]. The self-disclosure content of the robot was created based on the speech implemented in the commercial Pepper [60].

Additionally, in the "integrated life experiences session," the robot asked the participants about two topics: their "unforgettable experiences in life" and "what they thought was important in life from those experiences." These two topics were selected from Suganuma's [24] self-disclosure topics on integrated life experiences. In addition, when appropriate, the robot asked the participants questions about their experience, for example, "Is there anything you noticed that reminds you of this experience?" and "Was there a reason you started doing it?"

4.7 Procedure

On the day of the experiment, participants were individually invited to our laboratory, where they signed a consent form after a detailed explanation of the experiment.

The participants were then asked to respond to a pre-experiment questionnaire, which comprised questions framed to measure their generativity, self-esteem, and impressions of NAO [49], which was already in the same room.

Next, the first self-disclosure session, the "everyday experiences session," was conducted. This session did not exceed 10 min. When the participants' speech continued for more than 10 min, the robot terminated the session by saying "It's been 10 min, let's end it. Thank you for sharing this information with me."

The participants were asked to answer a between-sessions questionnaire after the "everyday experiences session." Similar to the pre-experiment questionnaire, the participants answered questions regarding their generativity, self-esteem, and impressions of the robot.

Before the "integrated life experiences session," we prepared the integrated life experience self-disclosure content for the participants. The participants were given a paper and instructed to write about their "unforgettable experience" and "what they thought was important in life from that experience." The preparation time was limited to a maximum of 5 min.

The second self-disclosure session, the "integrated life experiences session," was conducted after confirming that the participants were ready for conversation with the robot. This session was limited to a maximum of 10 min. After the "integrated life experience self-disclosure session," participants were asked to answer a post-experiment questionnaire. They answered questions about their willingness to self-disclose to the robot, as well as their generativity, self-esteem, and impressions of the robot.

Finally, the participants were asked to participate in the interview. The interviews took an average of 15 min to complete and the experiment was completed.

4.8 Measurement

Generativity Generativity was evaluated using the generativity-scale [61], which is the Japanese translation of the Loyola Generativity Scale (LGS) [62]. The scale has five subscales: creating, maintaining, offering, next generation, and symbolic immortality. Participants answered 20 questions using a five-point scale. The average scores of the responses to the items of each subscale were used as the "*creating*" score, "*maintaining*" score, "*offering*" score, "*next generation*" score, and "*symbolic immortality*" score. The total score was used in the analysis as "*generativity*" score.

Self-esteem To evaluate self-esteem, the RSES-J [63], which is a Japanese translation of the Rosenberg self-esteem scale (RSES) [64] was used. Participants answered 10 questions using a four-point scale. The total scores were used in the analysis as "*self-esteem*" score.

Impression of the robot The participants' impressions of the robot were measured by using the Godspeed questionnaire [65] with three subscales: likeability, anthropomorphism, and perceived intelligence. Although we used only the likeability subscale for testing H2-a, we also measured the anthropomorphism and perceived intelligence subscales to further explore the influence of change in listening attitude. Participants responded to each of the 15 items using a semantic differential scale. The averages scores of the responses to the items corresponding to each subscale were used as the "*liking*" score, "*anthropomorphism*" score, and "*perceived intelligence*" score.

Willingness to self-disclose to the robot We used a scale to measure the participants' willingness to self-disclose to the robot based on Uchida et al. [18], who used an original scale in which participants indicated their willingness to self-disclose each topic from [27]. The participants evaluated their willingness to self-disclose each topic from Suganuma [24] using a seven-point Likert scale (1 = extremely unwilling to disclose and 7 = extremely willing to disclose). These 16 questions are shown in the Appendix. Self-disclosure topics comprise 16 items and three factors: integrated life experience (seven items), everyday experience (four items), and loss experience (five items) [10]. The average scores of the responses to the items of each self-disclosure factor were

used in the analysis as "*integrated life experience*" score, "*everyday experience*" score, and "*loss experience*" scores.

5 Results

5.1 Increase in Generativity (Test of H1-a)

From H1-a, the self-disclosure of integrated life experiences to robots improves the generativity of the elderly. To test H1-a, we conducted a 3×2 two-way repeated measures ANOVA using *generativity* score as the characteristic variable, *measurement time point* (pre-experiment, between-sessions or post-experiment) as a within-participants variable and *robot's listening attitude* (consistently positive or change) as a between-participants variable. The *generativity* score was the total score of all 20 question items on the generativity scale [61]. Cronbach's alpha for the 20 items was 0.891.

We did not observe a significant main effect of *measurement time point* (F [2,72] = 0.254, $p = 0.776$, $\eta_p^2 = 0.007$) or *robot's listening attitude* (F [1,36] = 2.62, $p = 0.114$, $\eta_p^2 = 0.068$). The interaction effect of *measurement time point* and *robot's listening attitude* was also not significant (F [2,72] = 0.382, $p = 0.684$, $\eta_p^2 = 0.011$).

Multiple comparisons using the Bonferroni's method, revealed that there were no significant differences in the *measurement time point* pairs.

We also explored that whether there were any increases in the following subscales of generativity: creating, maintaining, offering, next generation, and symbolic immortality. Cronbach's alpha was calculated for each subscale item. The results revealed that two subscale values were greater than 0.70 (*creating* = 0.726, *symbolic immortality* = 0.734), and other three subscales' values were not (*maintaining* = 0.636, *offering* = 0.639, *next generation* = 0.577). Therefore, we conducted a 3×2 two-way repeated measures ANOVAs using only *creating* score and *symbolic immortality* as the characteristic variables, *measurement time point* (pre-experiment, between-sessions or post-experiment) as a within-participants variable and *robot's listening attitude* (consistently positive or change) as a between-participants variable.

In the analysis of the *creating* scores, Mauchly's sphericity test revealed that sphericity was violated ($\chi^2(2) = 7.01$, $p = 0.030$). Therefore, we corrected the degrees of freedom using the Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.846$). Consequently, we observed *measurement time point* (F [1.69,62.9] = 2.79, $p = 0.078$, $\eta_p^2 = 0.072$) and *robot's listening attitude* (F [1,36] = 3.15, $p = 0.084$, $\eta_p^2 = 0.081$) had marginal effect. The interaction effect of *measurement time point* and *robot's listening attitude* was not significant (F [1.69,62.9] = 0.447, $p = 0.609$, $\eta_p^2 = 0.012$). Multiple comparisons using Bonferroni's method, revealed that the scores of the post-experiment ($M = 3.63$, $SD = 0.704$) was significantly higher than those of the between-sessions ($M = 3.50$, $SD = 0.838$; $p = 0.035$, $d = 0.171$). The estimated means and standard errors of the *creating* scores at each *measurement time point* are shown in Fig. 4.

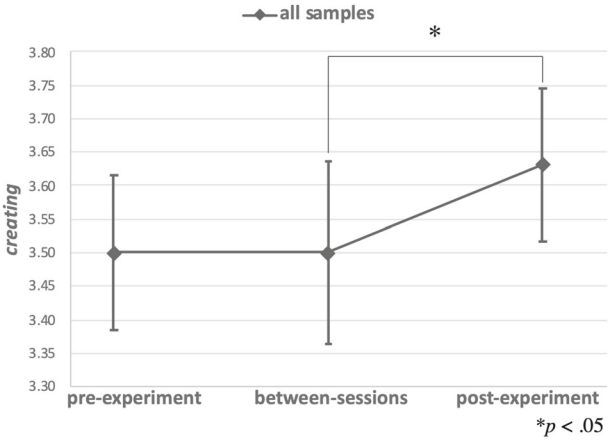

Fig. 4 Estimated means and standard errors of *creating* scores at each *measurement time point* levels

In the analysis of *symbolic immortality*, we did not observe any significant main effect of *measurement time point* (F [2,72] = 1.04, $p = 0.360$, $\eta_p^2 = 0.028$), and *robot's listening attitude* (F [1,36] = 1.739, $p = 0.196$, $\eta_p^2 = 0.046$). The interaction effect of *measurement time point* and *robot's listening attitude* was also not significant (F [2,72] = 0.414, $p = 0.663$, $\eta_p^2 = 0.011$).

Multiple comparisons using Bonferroni's method, revealed that there were no significant differences in *measurement time point* pairs.

In summary, we did not observe an increase in the *generativity* score; however, the *creating* score after the self-disclosure of integrated life experiences to the robot increased. Hence, H1-a was partially supported.

5.2 The Increase in Self-esteem (Test of H1-b)

From H1-b, the self-disclosure of integrated life experiences to robots improves the self-esteem in the elderly. To test H1-b, we conducted a 3×2 two-way repeated measures ANCOVA using *self-esteem* as the characteristic variable, *measurement time point* (pre-experiment, between-sessions or post-experiment) as a within-participants variable, *robot's listening attitude* (consistently positive or change) as a between-participants variable and *age* as a covariate. *Age* was used as a covariate because it was significantly correlated with the change in the *self-esteem* scores of the between the between-sessions and post-questionnaire (r = −0.321, *p*

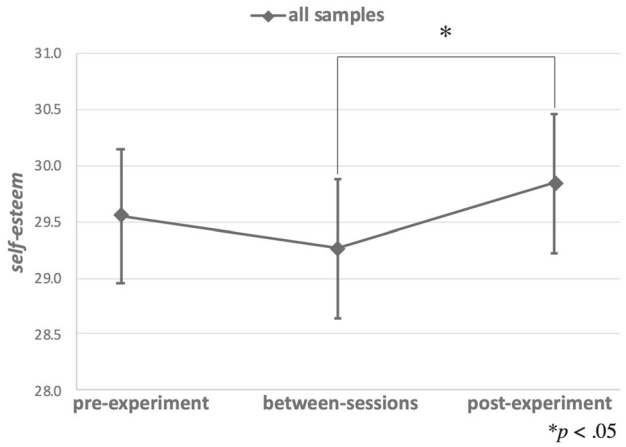

Fig. 5 Estimated means and standard errors of *self-esteem* scores at each *measurement time point* levels

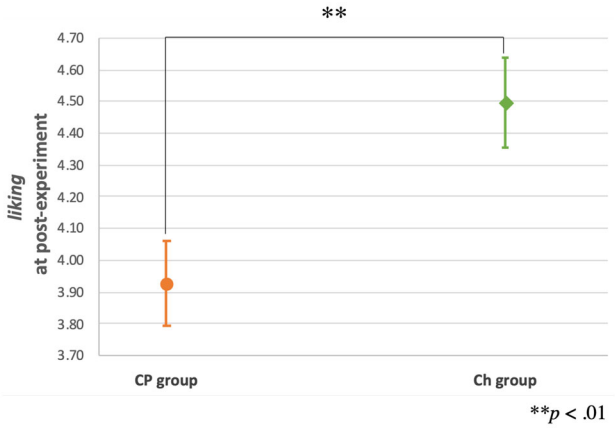

Fig. 6 Estimated means and standard errors of post-experiment *liking* scores based on *robot's listening attitude* levels

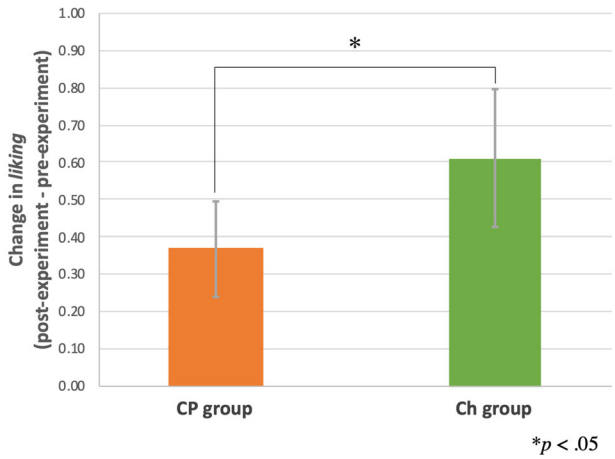

Fig. 7 Estimated means and standard errors of the change amount of *liking* scores from pre- to post-experiment based on *robot's listening attitude* levels

= 0.049). The *self-esteem* score was the total score of all 10 question items in the RSES-J [63]. A Cronbach's alpha for the 10 items was 0.826.

Mauchly's sphericity test revealed that the sphericity was violated ($\chi^2(2) = 8.30$, $p = 0.016$). Therefore, we corrected the degrees of freedom using the Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.822$). We did not observe a significant main effect of *measurement time point* (F [1.64,57.5] = 2.14, $p = 0.136$, $\eta_p^2 = 0.058$) or *robot's listening attitude* (F [1,35] = 0.471, $p = 0.497$, $\eta_p^2 = 0.013$). The interaction effect of *measurement time point* and *robot's listening attitude* was also not significant (F [1.64,57.5] = 1.47, $p = 0.233$, $\eta_p^2 = 0.40$). Multiple comparisons using Bonferroni's method, revealed that the scores of the post-experiment ($M = 29.8$, $SD = 3.83$) was significantly higher than those of the between-sessions ($M = 29.3$, $SD = 3.82$; $p = 0.044$, $d = 0.151$). The estimated means and standard errors of *self-esteem* scores at each *measurement time point* are shown in Fig. 5.

In summary, we observed an increase in *self-esteem* scores after the self-disclosure of integrated life experiences to the robot. Hence, H1-b was supported.

5.3 Difference Between the Two Groups' Liking for the Robot (Test of H2-a)

From H2-a, the participants appeared to like the robots better when their listening attitudes were positively changing, rather than consistently positive. To test H2-a, we conducted a t-test on the *liking* scores of the post-experiment. A Cronbach's alpha for the five items of the *liking* subscale was 0.903. The results revealed a significant difference between the CP ($M = 3.93$, $SD = 0.586$) and Ch ($M = 4.49$, $SD = 0.612$; $p = 0.006$, $d = 0.949$) groups. The estimated means and standard errors of the post-experiment *liking* scores based on *robot's listening attitude* levels are shown in Fig. 6.

Furthermore, we conducted a one-way ANCOVA using the change in the *liking* scores from pre- to post- *liking* score as the characteristic variable, *robot's listening attitude* (consistently positive or change) as a between-participants variable and *age* and the *liking* scores in the pre-experiment as covariates. *Age* was used as a covariate because it was moderately correlated with the post-experiment *liking* score (r = 0.309, $p = 0.059$). To avoid bias by statistical regression toward the mean [66], we used the *liking* scores in the pre-experiment as a covariate. The results revealed the *robot's attitude change* had a significant effect (F [1,35] = 5.65, $p = 0.023$, $\eta_p^2 = 0.139$). The estimated means and standard errors of the change in the *liking* scores from pre-experiment to post-experiment based on *robot's listening attitude* levels are shown in Fig. 7.

In summary, we observed that the *liking* scores of the Ch group after the experiment were significantly higher than those of the CP group. The change in the liking scores of the

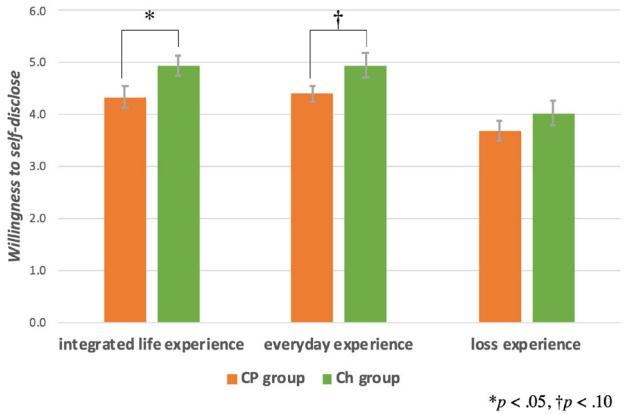

Fig. 8 Estimated means and standard errors of "*integrated life experience*" scores, "*everyday experience*" score and "*loss experience*" score based on *robot's listening attitude* levels

pre- to post-experiment between the two groups was significant, which supported H2-a.

5.4 Difference Between the Two Groups' Willingness to Self-disclose to the Robot (Test of H2-b)

From H2-b, the participants appeared to be willing to self-disclose to the robots more when their listening attitudes were positively changing, rather than consistently positive. To test H2-b, we conducted t-tests on the "*integrated life experience*" scores, "*everyday experience*" score and "*loss experience*" scores. Cronbach's alphas of question items of the three subscales were greater than 0.70 ("*integrated life experience*" score = 0.877, "*everyday experience*" score = 0.741 and "*loss experience*" score = 0.853).

In the analysis of the "*integrated life experience*" scores, we observed a significant difference between the CP (M = 4.34, SD = 0.886) and Ch (M = 4.94, SD = 0.901; p = 0.045, d = 0.673) groups.

In the analysis of the "*everyday experience*" scores, we observed a marginally significant difference between the CP (M = 4.41, SD = 0.668) and Ch (M = 4.95, SD = 1.03; p = 0.064, d = 0.620) groups.

In the analysis of the "*loss experience*" scores, we did not observe a significant difference between the CP (M = 3.68, SD = 0.878) and Ch (M = 4.03, SD = 1.04; p = 0.273, d = 0.361) groups.

The estimated means and standard errors of the "*integrated life experience*" scores, "*everyday experience*" score and "*loss experience*" scores based on *robot's listening attitude* levels are shown in Fig. 8.

In summary, we observed the result that the *willingness of self-disclosure* scores of the Ch group was significantly higher than those of the CP group in terms of integrated life experiences and everyday experiences but not in terms of loss experiences. Hence, H2-b was partially supported.

5.5 Difference Between Two Groups' Increase of Generativity (Test of H3-a)

From H3-a, compared with the elderly who self-disclosed to a robot with consistently positive listening attitudes, those who self-disclosed to a robot with positively changing listening attitudes showed a larger improvement in generativity. To test H3-a, we conducted a one-way ANCOVA using the change in the *generativity* scores from between-sessions to post-experiment as the characteristic variable, *robot's listening attitude* (consistently positive or change) as a between-participants variable and the *generativity* score between-sessions as a covariate. The *generativity* score between-sessions was used as a covariate to avoid bias by statistical regression toward the mean [66]. The results revealed that the *robot's attitude change* did not have a significant effect (F [1,35] = 0.695, p = 0.410, η_p^2 = 0.019).

In summary, we did not observe a difference in the change in the *generativity* scores of the between the two groups. Hence, H3-a was rejected.

5.6 Difference Between Two Groups' Increase of Generativity (Test of H3-b)

From H3-b, compared with the elderly who self-disclosed to a robot with consistently positive listening attitudes, those who self-disclosed to a robot with positively changing listening attitudes showed a larger improvement in self-esteem. To test H3-b, we conducted a one-way ANCOVA using the change in the *self-esteem* scores from between-sessions to post-experiment as the characteristic variable, *robot's listening attitude* (consistently positive or change) as a between-participants variable and *age* and the *self-esteem* score between-sessions as covariates. *Age* was used as a covariate because it was significantly correlated with the change in the *self-esteem* scores from the between-sessions and the post-experiment questionnaires (r = −0.321, p = 0.049). Moreover, to avoid bias by statistical regression toward the mean [66], we used the *self-esteem* score between-sessions as a covariate. The results revealed that *robot's attitude change* was marginally significant (F [1,34] = 2.92, p = 0.097, η_p^2 = 0.079). The estimated means and standard errors of the change in the *self-esteem* scores from between-experiment to post-experiment by *robot's listening attitude* level are shown in Fig. 9.

In summary, we observed a trend toward differences in the change in *self-esteem* scores of the between the two groups. Hence, we reserved the judgment on whether H3-b was supported or rejected in this study.

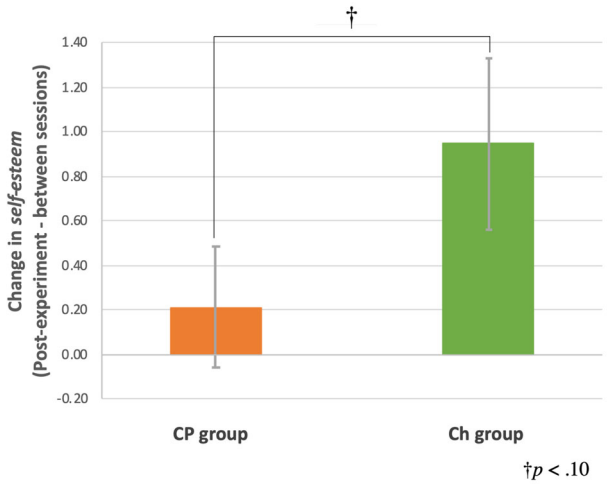

Fig. 9 Estimated means and standard errors of the change in *self-esteem* scores from between-experiment to post-experiment based on *robot's listening attitude* levels

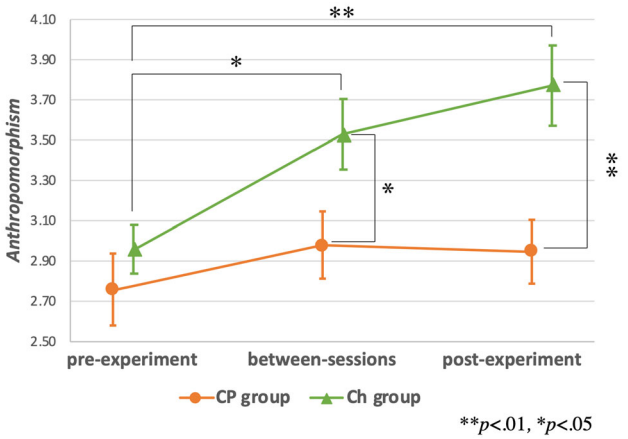

Fig. 10 Estimated means and standard errors of the *anthropomorphism* scores in each *measurement time point* based on *robot's listening attitude* levels

5.7 Difference Between Two Groups' Anthropomorphism and Perceived Intelligence of Both Groups

We conducted a a 3×2 two-way repeated measures ANOVA using the "*anthropomorphism*" and "*perceived intelligence*" scores as the characteristic variable, *measurement time point* (pre-experiment, between-sessions or post-experiment) as a within-participants variable and *robot's listening attitude* (consistently positive or change) as a between-participants variable. Cronbach's alpha for the five items of the *anthropomorphism* subscale was 0.861 and that of the five items of the *perceived intelligence* was 0.850.

Differences in anthropomorphism between the two groups In the analysis of the *anthropomorphism* scores, Mauchly's sphericity test revealed that sphericity was violated ($\chi^2(2) = 8.312, p = 0.016$). Therefore, we corrected the degrees of freedom using the Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.825$). The results revealed that a significant interaction effect between *measurement time point* and *robot's listening attitude* (F [1.65,59.4] = 3.77, $p = 0.036$, $\eta_p^2 = 0.095$).

Therefore, we conducted a one-way ANOVAs using the *anthropomorphism* scores in the three *measurement time points* (pre-experiment, between-sessions or post-experiment) as the characteristic variables and *robot's listening attitude* (consistently positive or change) as the between-participants variable.

Based on the analysis of the *anthropomorphism* scores of the pre-experiment, the effect of *robot's listening attitude* was not significant (F [1,36] = 0.863, $p = 0.359$, $\eta_p^2 = 0.023$).

Based on the analysis of the *anthropomorphism* scores of the between-sessions, the effect of *robot's listening attitude* was significant (F [1,36] = 5.02, $p = 0.31$, $\eta_p^2 = 0.122$).

Based on the analysis of the *anthropomorphism* scores of the post-experiment, the effect of *robot's listening attitude* was significant (F [1,36] = 10.2, $p = 0.003$, $\eta_p^2 = 0.221$).

Next, we conducted a one-way repeated ANOVA using the *anthropomorphism* scores as the characteristic variable and *measurement time point* (pre-experiment, between-sessions or post-experiment) as the within-participants variable for each of the CP and Ch groups.

In the analysis the *anthropomorphism* scores of the CP group, the main effect of *measurement time point* was not significant (F [2,36] = 1.72, $p = 0.194$, $\eta_p^2 = 0.087$).

In the analysis the *anthropomorphism* scores of the Ch group, the main effect of *measurement time point* was not significant (F [2,36] = 9.97, $p < 0.001$, $\eta_p^2 = 0.356$). Multiple comparisons using the Bonferroni's method, revealed that the scores of the post-experiment ($M = 3.77$, $SD = 0.880$; $p = 0.019$, $d = 0.853$) and those of the between-sessions ($M = 3.53$, $SD = 0.772$; $p = 0.005$, $d = 1.11$) were significantly higher than those of the pre-experiment ($M = 2.96$, $SD = 0.540$).

The estimated means and standard errors of the *anthropomorphism* scores in each *measurement time point* based on *robot's listening attitude* levels are shown in Fig. 10.

Differences in perceived intelligence between the two groups In the analysis of the *perceived intelligence* scores, Mauchly's sphericity test revealed that sphericity was violated ($\chi^2(2) = 6.488, p = 0.039$). Therefore, we corrected the degrees of freedom using the Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.855$). The results revealed that there was a significant interaction effect between *measurement time point* and *robot's listening attitude* (F [1.71,61.6] = 3.51, $p = 0.043$, $\eta_p^2 = 0.89$).

Therefore, we conducted a one-way ANOVAs using the *perceived intelligence* scores in the three *measurement time points* (pre-experiment, between-sessions or post-

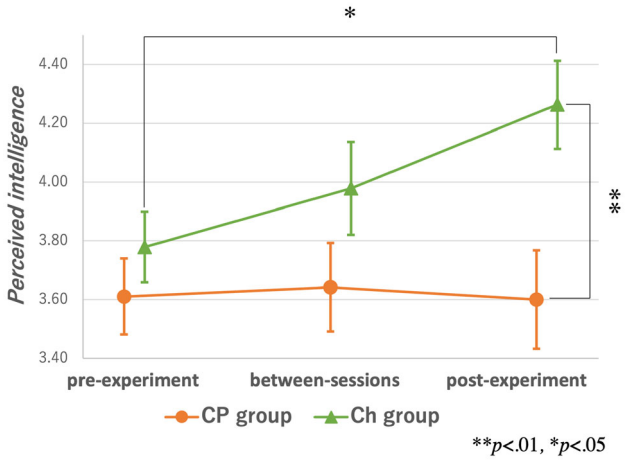

Fig. 11 Estimated means and standard errors of the *perceived intelligence* scores in each *measurement time point* based on *robot's listening attitude* levels

experiment) as the characteristic variables and *robot's listening attitude* (consistently positive or change) as a between-participants variable.

In the analysis of the *perceived intelligence* scores of the pre-experiment and between-sessions, the effect of *robot's listening attitude* was not significant (pre-experiment: F [1,36] = 0.909, $p = 0.347$, $\eta_p^2 = 0.025$, between-sessions: F [1,36] = 1.08, $p = 0.131$, $\eta_p^2 = 0.062$).

In the analysis of the *perceived intelligence* scores of the post-experiment, the effect of *robot's listening attitude* was significant (F [1,36] = 8.70, $p = 0.006$, $\eta_p^2 = 0.195$).

Next, we conducted a one-way repeated ANOVA using the *perceived intelligence* score as the characteristic variable and *measurement time point* (pre-experiment, between-sessions or post-experiment) as a within-participants variable for each of the CP and Ch groups.

In the analysis of the *perceived intelligence* scores of the CP group, Mauchly's sphericity test revealed that sphericity was violated ($\chi^2(2) = 6.463$, $p = 0.040$). Therefore, we corrected the degrees of freedom using the Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.760$). The main effect of *measurement time point* was not significant (F [1.52,27.4] = 0.056, $p = 0.904$, $\eta_p^2 = 0.003$).

In the analysis of the *perceived intelligence* scores of the Ch group, we observed that the main effect of *measurement time point* was significant (F [2,36] = 6.23, $p = 0.005$, $\eta_p^2 = 0.257$). Multiple comparisons using the Bonferroni's method, revealed that the scores of the post-experiment ($M = 4.26$, $SD = 0.653$) were significantly higher than those of the pre-experiment ($M = 3.78$, $SD = 0.524$; $p = 0.020$, $d = 0.817$).

The estimated means and standard errors of the *perceived intelligence* scores in each *measurement time point* based on *robot's listening attitude* levels are shown in Fig. 11.

6 Discussion

6.1 Effect of Self-disclosure on Elderly People's Generativity and Self-esteem

First, we discuss why the participants' *creating* scores improved after self-disclosure to the robot. The conversation experiences may have influenced this. One of the two question items relating to *creating* in LGS [62] was "*Other people say that I am a very productive person.*" The generativity-scale [61], which was the Japanese translated version of LGS [62], used the word "Maemuki" as the translation of "productive." "Maemuki" can also translated to as "positive." In the interviews, some participants revealed that the interaction with the state-of-the-art robot would make them think positively about their lives. For instance, one participant said, "*If I can stay alive, I can see more and more evolution. So I want to live long, and I will see.*" Others said that "*I hope you continue to do this kind of thing, is it not fun to see the progress?*" This positive feeling in relation to life might have improved their *creating* score.

As denoted in Sects. 5.1 and 5.2, the *self-esteem* scores, unlike the *generativity*, increased. We believe that the difference between two measurements contributed to this result. For generativity to develop, interest, involvement, and commitment to *others*, especially the next generation, are considered essential [67]. On the other hand, self-esteem was defined as "a level of self-evaluation that is created and maintained *by oneself*, which is expressed either positively or negatively" [68]. The presence of *others* is crucial for improving generativity, but self-esteem can be improved while being alone. We believe that our robot cannot serve as a substitute for humans. This is because some participants mentioned, "*It is not possible for a robot to know what we are talking about, so I would rather self-disclose to humankind than robot.*" However, we believe that our robot facilitated self-disclosure and introspection by the elderly, something they do not usually do easily. One participant said, "*Because it is a robot, it was very easy to construct a story in my head, which is good because there are no objections.*" Others said that "*There may be a role for robots as a facilitator that encourages them to talk.*"

As for the result in Sect. 5.6, we observed the trend of the difference between the two groups' change in the *Self-esteem* score. This may be because the sample size was not sufficient. A larger sample size is required to clarify these results.

6.2 The Influence of Robots Listening Attitude Change

As stated in Sect. 5.3, we observed that the elderly liked the robot that changed its listening behavior from neutral to

positive more than they did the robot that behaved consistently positively. In the interview, one participant said, "*At first, I thought it was mechanical, but as we talked more and more, I began to feel closer to him. I was happy to hear his responses.*" Another participant said, "*It was like you were relaxing. I thought the robot was adjusting to me, too.*" The change in the robots' behavior as the participants and the robot got to know each other may have led to increased fondness.

Furthermore, in the results in Sect. 5.7, the anthropomorphism and perceived intelligence of the robot were also influenced by the change in the robot's listening attitude. This could be attributed to the fact that the participants thought that the robot changed its listening behavior because of the changes in conversation topics, not because of time. In this study, the listening behavior of the robot the Ch group participants interacted with was neutral behavior during the first self-disclosure session and positive during the second session. The conversation topics of the first and second self-disclosure sessions were everyday experiences and integrated life experiences, respectively.

Based on the results of the interviews, it appears that the participants found the robot to be human-like and smart enough to change their attitudes according to the theme of the conversation. One participant said that "*I felt humanized and deeply included in the process. When the robot leaned in and listened to me as hard as they could, I felt like the robot understood and knew me.*"

We decided on this conversation topic sequence because the content of self-disclosure between the two parties gradually deepens [33]. Topics about integrated life experiences are thought to have deeper content than topics about everyday experiences. The changes in the robot's listening behavior were fixed on the topic of the conversation and were similar to the changes in the human listening behavior, where the deeper the topic, the more carefully they listened.

6.3 Difference of Self-disclosure Topics

As mentioned in Sect. 5.4, we observed that the change in the robot's listening attitude had a positive effect on the elderly's willingness to self-disclose to the robot in terms of integrated life experiences and everyday experiences, but not loss experiences. There was no difference between the two groups because it was difficult for the participants to recall of the self-disclosure of the loss experience. The participants self-disclosed their everyday and integrated life experiences during the experiment. By contrast, they did not self-disclose of loss experiences. The fact that only the loss experience was not self-disclosed may be the reason why the scores were low across the two groups and no difference was observed.

It is also possible that the characteristics that people look for in a robot may differ from those of other self-disclosure topics in their willingness to self-disclose their loss experience. For example, a less anthropomorphic robot may be suitable. This is because, in terms of the topic of the most embarrassing moments, children with autism spectrum disorder disclose more to the visually simple robot than to the android robot when talking [38]. Additionally, additional functionality may be required. One participant said, "*If I could talk about health and get appropriate advice back, I would.*"

6.4 Pre-existing Expectations for Robots

As mentioned in Sect. 4.4, we replaced Pepper, which was used in our preliminary experiments [23], with NAO. This was because of prior robot expectations of the participants had. In Japan, Pepper is currently being introduced to cell phone retailers and conveyor belt sushi restaurants throughout the city. Some of the participants in the preliminary experiment had experienced conversing with Pepper and had a prior expectation that Pepper's conversational response capabilities would be high. However, the Pepper conversational response program used in the experiment was created by the experimenter for this preliminary experiment, and it had fewer response variations than the commercial Pepper. Furthermore, because the experimenter operated the program in response to the participants' speech, there was a delay in the response. This meant that the participants' high expectations of Pepper's conversational response capabilities were not met, and they were disappointed. For example, "*I thought a little like this. Was it like this when we talked about before? Was it this bad at pausing?*" and "*I have known Pepper for a few years, so I have an image of him. I had my own expectations for Pepper, so I was a little disappointed.*"

Therefore, NAO was used in this experiment because it is not commercially available, and few people have had experience with it. The results of the interviews for this experiment showed that no participant found NAO disappointing. In summary, the results revealed that the participants referred to their prior impressions of the robot when evaluating their impressions of the robot they conversed with in the laboratory experiment. Thus, it can be said that when conducting experiments, a robot platform with which the participants have little conversational experience, and have thus not formed an impression on, should be used.

Furthermore, we believe that NAO did not disappoint the participants because they did not have high expectations of performance generated by the first visit. One participant commented, "*It looks like a toddler or an elementary school student because of its small size, but I was surprised at how smart it is.*" Another participant praised its appearance, citing Pepper's by saying "*Pepper is cute, but NAO is more familiar to me. NAO has a more human-like body.* " This result is consistent with previous studies that found that robots

with simpler or friendlier appearances were preferred over androids as self-disclosure partners [38,39].

6.5 Limitation and Future Works

First, the experiment time was only 20 min for each participant. Longer experiments are required to simulate real-life situations in which the robot can be used in the real world. It would be even better if the robot could be deployed in the participant's home, providing freedom to interact with the robot and self-disclose at the time and frequency of the participant's choice.

Moreover, the effects of temporal changes in listening attitudes and that of a combination of listening attitudes and self-disclosure topics were not distinguished in this study. Specifically, the effect of temporal changes refers to the change in listening attitudes from neutral to positive over time. On the other hand, the effect of combination refers to the effect of neutral listening attitudes on self-disclosure of everyday experiences and that of positive listening attitudes on self-disclosure of integrated life experiences. To determine the more dominant of these two effects, two new experiment groups were necessary. In the first group, a robot with a positive listening attitude listened to the self-disclosure of integrated life experiences in the first session and a robot with a neutral listening attitude listens to the self-disclosure of everyday experiences in the second session (combination-only group). In the second group of experiments, the robot had a neutral listening attitude to the self-disclosure of integrated life experiences in the first self-disclosure session and a positive listening attitude to the self-disclosure of everyday experiences in the second self-disclosure session (temporal change-only group). By comparing the individual measures of the two groups, we examined the differential influence of the combined change and time-varying effects. However, these two groups may be difficult to implement because their design counter the social penetration theory [33]. The social penetration theory predicts that, as the relationship between two parties grows from the initial meeting to intimacy, the intimacy of the self-disclosures exchanged with each other also increases. Therefore, it will be difficult for the participants to self-disclose their integrated life experiences to a robot during the first self-disclosure session. Consequently, it would be difficult to test the separate effects of temporal change and combination in a short experiment such as this one. Therefore, it is necessary to conduct a longer experiment.

In addition, although we used only self-report questionnaires, objective measures, such as participants' emotional state, physical health, and activity level, would provide useful data to further understand the effects of robot-mediated self-disclosure in the elderly. Furthermore, the participants of this study were elderly Japanese individuals. It is necessary to verify the applicability of the effect of the robot's attitude change to people of different ages and cultures. We experimented with only the humanoid robot Nao. It is also important to verify whether the change in listening attitude is effective, even with animal-like robots or unembodied agents.

A potential development of this research is the design of a robot that can improve the generativity of the elderly. As mentioned in Sect. 6.1, robots must be recognized as others to improve their generativity. This is a challenging task in the field of human–robot interactions.

7 Conclusion

The purpose of this study was twofold: to determine the impact of self-disclosure of integrated life experiences to a robot on the elderly and to determine the effect of changes in the listening attitude of the robot on the elderly's self-disclosure of integrated life experiences. We conducted an experiment with 38 elderly participants who were more than 60 years old. The participants self-disclosed to the robot for approximately 20 min. They were assigned to either the CP group, where they interacted with a robot with a consistently positive listening behavior, or the Ch group, where they interacted with a robot whose listening behavior was first neutral and, subsequently, positive. The results revealed that participants' self-esteem increased after self-disclosure of integrated life experiences. The increase in self-esteem tended to be higher in the Ch group than that in the CP group. Moreover, the Ch group participants evaluated the robot as more likable and were more willing to self-disclose to the robot than the CP group participants.

Data Availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare no conflicts of interest associated with this manuscript.

Appendix

Questionnaire on the willingness to self-disclosure to the robot Participants indicated the degree to which they would like to disclose the following items to "Nao" on a scale of one to seven (1: extremely unwilling to disclose; 2, quite unwilling to disclose; 3, somewhat unwilling to disclose; 4, neither unwilling nor willing to disclose; 5, somewhat willing to disclose; 6, quite willing to disclose; and 7, extremely

willing to disclose). In the experiment, the following total of 16 questions were randomly placed. The following questionnaire was translated into English for publication. A Japanese questionnaire was used in the experiment.

Integrated Life Experiences

1. I want to talk about the beliefs I have gained in my life.
2. I would like to reflect on an unforgettable experience.
3. I have something new to start.
4. I'm glad I found something new.
5. I want to preserve the history of my life.
6. I want something I can get lost in, but I'm having a hard time finding it.
7. I have a place I want to go out.

Everyday Experiences

1. I'm having fun and I'm elated.
2. I want to pass on the wisdom I have acquired in my daily life.
3. I feel awkward and bothered by socializing with others.
4. I am concerned about my chronic illness.

Loss Experiences

1. I'm worried about my health.
2. I'm in trouble because I want a lot of money.
3. I am wondering how I will live my life from now on.
4. I'm worried about the money I'll need in the future.
5. I would like to make more acquaintances, but I am lonely because I haven't found a good way to do so.

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