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Development of depression assessment tools using humanoid robots -Can tele-operated robots talk with depressive persons like humans?

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A R T I C L E I N F O

Keywords:
Major depressive disorder (MDD)
Humanoid robot
Communication robot
Hamilton depression rating scale (HDRS)
Telepsychiatry

A B S T R A C T

Background: Depression is a common mental disorder and causes significant social loss. Early intervention for depression is important. Nonetheless, depressed patients tend to conceal their symptoms from others based on shame and stigma, thus hesitate to visit psychiatrists especially during early phase.
We hypothesize that application of humanoid robots would be a novel solution. Depressed patients may feel more comfortable talking with such robots than humans.
Methods: We recruited 13 patients with major depressive disorder (MDD) and 27 healthy volunteers as controls. Participants took both tele-operated humanoid robot and human interviews to evaluate severity of depression using the Hamilton Depression Rating Scale (HDRS). In addition, participants completed a self-administered questionnaire asking about their impressions of the robot interview.
Results: Confidence interval and *t*-test analysis have revealed that the HDRS scores are equally reliable between robot and human interviews. No significant differences were observed between the two interviews regarding "nervousness about the interview" and "hesitancy to talk about depressed moods and suicidal ideation." Compared to human interviews, robot interviews yielded significantly lower scores on shame-related factors especially among patients with MDD.
Limitation: Small sample size, and the evaluator is male only.
Conclusions: This is the first report to show the reliability of tele-operated humanoid robot interviews for assessment of depression. Robot interviews are potentially equally reliable as human interviews. Robot interviews are suggested to be more appropriate in assessing shame-related suppressed emotions and hidden thoughts of depressed patients in clinical practice, which may reduce the stigma associated with depression.

1. Background

Depression is a common mental disorder, and the prevalence of major depression disorder (MDD) is known to be among one in six adults (Kessler and Bromet, 2013; Otte et al., 2016). Depression impairs thinking, perception, emotions, and behavior, causing significant distress and impairment of personal functioning (Wakefield, 2007). The personal and social impacts of depression are significant (Bruffaerts et al., 2012), and depression ranks second in GBD (Global Burden of Disease)(Vos et al., 2015). Depression accounts for up to 32% of YLD (Years Lived with Disability) and over 13% of DALYs (Disability Adjusted Life Years)(Vigo et al., 2016). Depression is significantly associated with suicide, and depression accounts for 46% of suicides (Ferrari et al., 2014; Gili et al., 2019; Too et al., 2019).

The stigma attached to mental illnesses makes early detection and intervention of depression difficult (Editional, 2022; Sartorius et al., 2010). Patients with depression sometimes hide their symptoms and attempt suicide before seeking medical attention (Bell et al., 2011; Mitchell et al., 2009). Shame and self-stigma about having a mental illness also contribute to a reluctance to see a doctor or report mental symptoms to others (Editional, 2022; Herrman et al., 2022; Sartorius et al., 2010).

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If such hesitation can be eliminated through communication using a non-human medium, we can detect and support depressed patients at much earlier stage. Tele-operated humanoid robots are attracting attention as a tool to conduct interviews using a non-human medium. Robot interviewing has been reported to be effective, especially for patients with autism spectrum disorder (Kumazaki et al., 2018a, 2018b, 2019a). We hypothesize that depressed patients worring about shame would be more honest with a humanoid robot than with a human about symptoms they tend to hide. In a recent pilot trial, we conducted tele-operated humanoid robot interviews with two patients with depression in an outpatient setting. We found a tendency that they may be more honest about their inner self to the robots and that patients with depression were more truthful in the robot interview (Yoshikawa et al., 2021).

To date, no studies have examined the validity of assessing the severity of depressive symptoms in patients with depression using robot interviews. The purpose of this study is to evaluate the usefulness of robot interviews in the assessment of depression by comparing robot and human interviews. Based on our preliminary findings (Yoshikawa et al., 2021), we hypothesize that "depressed patients would be more honest to talk about their inner feelings with a robot." To test the hypothesis, we herein conducted a case-control study to validate the impact of robot interviews for patients with MDD.

2. Methods

2.1. Settings

This study was conducted based on the Kyushu University Institutional Review Board for Clinical Research (2020-360), and was performed in accordance with the Declaration of Helsinki. Clinical patients with MDD were recruited at the Mood Disorder/Hikikomori Clinic in the Kyushu University Hospital and its related affiliations. Healthy volunteers as controls were recruited at Kyushu University campus. To be eligible for the current study, participants had to be at least 15 years old at the time of study enrollment. The purpose and methods of the study were explained to the participants. Then, participants were informed that their anonymity would be maintained and that their participation was voluntary. Participants provided written consent and received an incentive of a gift card worth ¥1000 (approximately US$8).

2.2. Participants

Fifty-five participants (26 clinical patients and 29 healthy volunteers) were recruited between February 2021 and October 2021. 13 of the 26 clinical patients fulfilled the Structured Clinical Interview for DSM-IV-TR (SCID-I) diagnosis of MDD (First et al., 2002). 27 healthy volunteers as healthy controls (HC) were confirmed to be free of psychiatric complications using the Mini International Neuropsychiatric Interview (M.I.N.I.) (Amorim, 2000). All participants were Japanese (Asian), and the interviews and questionnaires were conducted using Japanese language.

2.3. Self-rated questionnaires

All participants were administered a self-administered questionnaire, a robot interview, and a human interview. We used the self-administered questionnaires including The Patient Health Questionnaire (PHQ-9) (Kroenke et al., 2001) and Beck Depression Inventory Second Edition (BDI-II) (Beck et al., 1987, 1996; Kojima et al., 2002) to assess the severity of depression. To assess the presence or absence of autism tendencies, we used The Autism-Spectrum Quotient Japanese version (AQ-J) (Wakabayashi et al., 2004). We also used the robot Anshin scale (Kamide et al., 2015), a self-administered 7-point Likert scale, to assess one's sense of security toward robots. In addition, a self-administered 7-point Likert scale was administered before and after the interviews to rate how easy it was to talk to the robot. After the interviews, participants were also asked for their impressions in a free-text format.

2.4. Procedures

We used CommU for the robot interviews (Kumazaki et al., 2018a, 2018b, 2019b, 2019c, 2019d, 2020; Shimaya et al., 2016, 2018; Yoshikawa et al., 2019, 2021). CommU is a small-sized humanoid robot with a height of 30 cm and a weight of 740g. CommU is particularly good at controlling the direction of eye gaze. CommU can express various simple facial expressions by moving its gaze, blinking, and other small movements (Kumazaki et al., 2020).

We used the Hamilton Depression Rating Scale (HDRS) to assess the severity of depression (Hamilton, 1960; Williams, 1988) in robot and human interviews, respectively. The robot and human interviews were conducted randomly on the same day. A trained psychiatrist or psychologist conducted the operation of the robot and all human interviews. Artificial intelligence (AI)-operated and self-capacities robots are ideal tools, however we have not yet developed such AI-operated robots. Therefore, in this study, we applied the tele-operated robot manipulation procedure based on the Wizard-of-Oz method (Fraser and Gilbert, 1991), with the robot acting as the psychiatrist's avatar and conducting semi-structured interviews with the participants. Although our system is not an autonomous robot, but the present tele-operated system we adopted is very easy to learn to manipulate in about 5 min. The system can also take physical distancing and is easy to operate remotely.

Tele-operated robot interviews were conducted in a standard examination room, and CommU was placed where the medical staff usually is (Fig. 1). A psychiatrist in another room remotely controlled the robot. The answers from the participants were monitored and assessed by the psychiatrist using audio and video footage. In this study, the CommU asked participants to complete a pre-programmed HDRS semi-structured interview. The operator determined the timing of the questions by pressing a button on the computer program connected to the robot. CommU used interjections, such as "I see" and "hmmm" in response to the participants' answers before proceeding to the next question. The participant's reaction to the robot may change as the participant perceives that a human operates the robot. Therefore, the participants were not informed about how the robot was operated and how CommU assesses patients. As for the human interviews, a psychologist conducted face-to-face evaluations as in a standard medical practice. Each interview was videotaped and later re-assessed by another psychiatrist to ensure the validity of the interviews.

2.5. Statistical analysis

Comparisons were made by grouping the participants into MDD group and HC group. Age, PHQ-9, and BDI-II were analyzed using the independent samples *t*-test. Gender was analyzed using the χ-square test. Total HDRS scores in the robot and human interviews were analyzed using the paired t-tests. Inter-rater reliability of each HDRS item was assessed using intraclass correlation coefficients (ICC) case 2. Each questionnaire item on the self-administered Likert scale of impressions of robots was compared using Wilcoxon's signed rank test with the corresponding sample. The sums of the questionnaire were compared using *t*-test or paired *t*-test. Statistical analyses were performed using IBM SPSS Statistics 28.0 for Mac OS. All analyses were significant at a probability of $p < 0.05$. All confidence intervals are two-sided.

3. Results

3.1. Participants characteristics

13 MDD patients and 27 HC participants were finally assigned to this

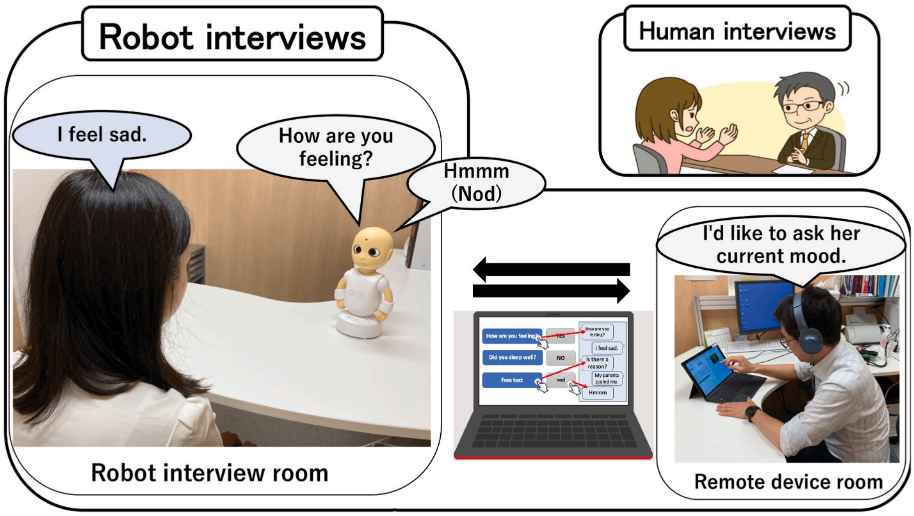

Fig. 1. Method of the robot and the human interviews.
The robot is teleoperated and talk to the participants alone. The robot operator selects each HDRS question by using a button, respectively. The operator can also type and send optional questions for the robot to ask the participants. The answers from the participants were monitored and assessed by the psychiatrist using audio and video footage.

case-control study. Demographics and clinical variables are summarized in Table 1. For PHQ-9 and BDI-II, there were significant differences between the MDD and HC groups. No significant differences were found between the MDD and HC groups for other items including AQ-J.

3.2. Impression of the robot

We conducted a self-administered questionnaire asking about the impression of the robot before and after the interview. Table 2 and Table 3 show the robot Anshin scale before and after the interviews that assessed the participant's general impression of robots. Both the MDD and HC groups showed significant differences in comfort, performance and controllability in paired *t*-test. We also compared the changes before and after between the MDD and HC groups using *t*-test. There was no difference in the trend of change between the MDD and HC groups.

3.3. Assessment of depression

For comparison validation, we conducted semi-structured interviews (17 items of the Hamilton Depression Rating Scale: HDRS) with a tele-operated humanoid robot (CommU) and a human psychologist. We compared the HAMD total scores for robot and human interviews in the MDD group using a paired *t*-test. The results indicated no statistically significant difference between the robot and human interviews, $t(12) = -1.488$, $p = 0.163$. The mean difference was −1.385 with a 95% confidence interval ranging from −3.412 to 0.643. The confidence interval is relatively small, thus we suppose that the HDRC scores are equally reliable between robot and human interviews (Walker and Nowacki, 2011).

ICC case 2 was used to confirm inter-rater reliability of HRDS; an ICC of 0.6 or higher is considered a substantial level (Landis and Koch, 1977). The ICC Case 2, for the total HDRS scores in this study, was 0.91, indicating sufficient inter-rater reliability. The robot interview using CommU was also reliable throughout as in previous studies (Moberg et al., 2001; Trajkovic et al., 2011)(Table 4).

Table 1
Demographic data of clinical patients and healthy volunteers (n = 40).

Characteristics	MDD (n = 13) (M, SD)	HC (n = 27) (M, SD)	Statistics		
			95%CI	t, χ2	p
Age in years	33.6 (12.4)	29.7 (10.7)	−3.754–11.651	1.038	0.306
Sex (female: male)	5:8	13:14	–	0.33	0.564
AQ-J	21.6 (7.8)	18.0 (7.3)	−2.003–9.27	1.316	0.198
PHQ-9	11.0 (7.9)	1.9 (2.4)	4.296–14	4.07	*0.001
BDI-II	18.7 (13.1)	2.9 (3.9)	7.87–23.965	4.272	*<0.01

Statistical P-values were derived from Student's t-test and chi-squared test. Significant P-values are marked with asterisks. (*P-value<0.05).
Abbreviations; MDD, major depressive disorder; HC, healthy controls; AQ-J, Autism Spectrum Quotient Japanese version; PHQ-9, The Patient Health Questionnaire; BDI-II, Beck Depression Inventory Second Edition.

3.4. Impression of robot and human interviews

We compared whether the participants felt comfortable talking to the robot before and after the CommU interviews using self-administered 7-point Likert scales (Table 5). The scores before and after the interview were evaluated by paired *t*-test. No significant change was found in the impression before and after the interview in the HC group.

In the MDD group, the scores of "The robot is easy to talk to" and "The robot is easier to talk to than people I often communicate with" were changed significantly. Changes in scores before and after the interviews for the MDD and HC groups were compared using t-tests (Table 6). There was no significant difference in the question "The robot is easier to talk to", but there was a significant difference in "The robot is easier to talk to than people I often communicate with". These results indicate that patients with depression may feel more comfortable talking to the robot than who they often communicate with.

Table 7 shows participants' impressions after the robot and human interviews. There were no significant differences between the MDD and HC groups in nervousness and hesitation to talk about their depressed mood or suicidal ideation in robot and human interviews. On sexual topics, both the MDD and HC groups were less shamed in the robot interview than in the human interview.

In the present study, there were more female than male participants in the MDD group, thus we sub-analyzed by gender (Table S1). Interestingly, in the MDD group, female participants were less shamed to talk with sexual issues in the robot interview than the human interview, whereas male participants with MDD were not significantly different. On the other hand, in the HC group, male participants were less shamed

Table 2
The scores of the sense of security scale before and after the robot interview.

		Mean	SD	95%CI	t	p
Comfortability	MDD	16.462	6.863	12.314–20.609	8.648	*<.001
	HC	16.692	9.393	12.899–20.486	9.062	*<.001
Stress	MDD	0.308	5.36	−2.931–3.547	0.207	0.84
	HC	1.704	4.573	−0.105–3.513	1.936	0.064
Performance	MDD	8.692	7.598	4.101–13.284	4.125	*0.001
	HC	9.148	9.367	5.443–12.854	5.075	*<.001
Controllability	MDD	21.846	6.694	17.801–25.891	11.767	*<.001
	HC	26.154	7.903	22.962–29.346	16.875	*<.001

Note; MDD, major depressive disorder; HC, healthy controls; N (MDD, HC = 13, 27); SD, Standard Deviation; CI, Confidence Interval.
Statistical P-values were derived from paired *t*-test. Significant P-values are marked with asterisks. (*P-value<0.05).

Table 3
The scores of comparing changes in the sense of security scale between the MDD group and the HC group.

	Mean	SD	95%CI	t	p
Comfortability	0.051	2.977	−5.975–6.078	0.017	1
Stress	−1.405	1.44	−4.32–1.511	−0.975	0.3
Performance	−0.179	2.476	−5.191–4.832	−0.073	0.9
Controllability	−2.538	2.022	−6.635–1.558	−1.255	0.2

Note; MDD, major depressive disorder; HC, healthy controls; N (MDD, HC = 13, 27); SD, Standard Deviation; CI, Confidence Interval.
Statistical P-values were derived from *t*-test. Significant P-values are marked with asterisks. (*P-value<0.05).

Table 4
Inter-rater reliability of HDRS items at intraclass correlation coefficients (ICC) case 2.

Table 3.	
Depression Scale Item	Robot study (MDD, n = 13)
Depressed mood	0.73
Feeling of guilt	0.63
Suicide	0.9
Insomnia early	0.71
Insomnia middle	0.84
Insomnia late	0.67
Work and activities	0.6
Psychomotor retardation	0.23
Psychomotor agitation	0.68
Anxiety psychotic	0.81
Anxiety somatic	0.67
Symptoms: Gastro intestinal	0.91
Symptoms: General	0.41
Genital symptoms	0.85
Hypochondriasis	0.29
Insight	–
Loss of weight	0.71
17 items	0.91

The results of ICC case 2 indicate inter-rater reliability. ICC is considered to have good reliability at 0.7 or higher. The "Insight" item could not be calculated due to a perfect alignment of results between the robot and human interviews.

in the robot interview than in the human interview, but the difference was not significant in females.

In the free comments after the robot interview, some participants noted that during in-person interviews, they sometimes mend their true opinions because they are concerned about what the other person thinks of them. Some participants commented that since the robot does not look at the assessment form, good eye contact and natural conversation are possible.

Table 6
The scores of comparing changes between the MDD group and the HC group in whether the participants felt comfortable talking to the robot before and after the robot interviews.

	Mean	SD	95%CI	t	p
The robot is easy to talk to	0.254	0.6	−0.962–1.469	0.422	0.675
The robot is easier to talk to than people who I often communicate with	0.954	0.439	0.065–1.844	2.172	*0.036

Note; MDD, major depressive disorder; HC, healthy controls; N (MDD, HC = 13, 27); SD, Standard Deviation; CI, Confidence Interval.
Statistical P-values were derived from *t*-test. Significant P-values are marked with asterisks. (*P-value<0.05).

Table 7
Participants' impressions after the robot and human interviews.

		Robot Mean (SD)	Human Mean (SD)	P-value
Nervousness	MDD	2.62(1.12)	2.85(1.14)	0.396
	HC	2.17(1.09)	2.58(1.10)	0.148
Hesitation: depression	MDD	2.00(1.00)	1.77(0.92)	0.18
	HC	1.71(1.04)	1.75(0.84)	0.783
Hesitation: suicidal ideation	MDD	1.92(1.03)	2.00(1.08)	0.785
	HC	1.54(0.93)	1.71(1.04)	0.461
Shame: sexual topics	MDD	2.38(1.38)	3.62(1.19)	*0.017
	HC	1.96(1.08)	2.54(1.17)	*0.006

Table 4 shows the participants' impressions after the robot and human interviews using a 7-point Likert scale. There were no significant differences between the robot and human interviews in terms of nervousness and hesitation. On the other hands, participants rated the robot interview as less shameful.
Statistical P-values were derived from Wilcoxon's signed rank test.
Significant P-values are marked with asterisks. (*P-value<0.05).

Table 5
The scores of whether the participants felt comfortable talking to the robot before and after the robot interviews.

		Mean	SD	95%CI	t	p
The robot is easy to talk to	MDD	0.846	1.144	0.155–1.537	2.668	*0.02
	HC	0.593	2.005	−0.201–1.386	1.536	0.137
The robot is easier to talk to than people who I often communicate with	MDD	0.769	1.166	0.065–1.474	2.379	*0.035
	HC	−0.185	1.36	−0.723–0.353	−0.708	0.485

Note; MDD, major depressive disorder; HC, healthy controls; N (MDD, HC = 13, 27); SD, Standard Deviation; CI, Confidence Interval.
Statistical P-values were derived from paired *t*-test. Significant P-values are marked with asterisks. (*P-value<0.05).

4. Discussion

This is the first study to validate the tele-operated humanoid robot interview with merits for assessing the severity of depression.

We hypothesized that "MDD patients tend to share their inner thoughts more honestly to non-human robots than to humans." Present outcomes have suggested that using robots and using humans are equally valid methods for interviewing about depressive symptoms. Furthermore, we have revealed that both MDD patients and healthy volunteers feel more comfortable disclosing their feelings especially for shame-related items, such as sexual questions, which have supported our hypothesis.

When asked about their level of shame towards discussing sexual topics, both MDD and HC groups felt significantly less shamed in the robot interview. Faber et al. has shown that patients with mental disorders are less likely to talk about their private regarding sexual topics to the therapist (Farber, 2003). On the other hand, we herein revealed that patients feel less shame and talk more about themselves when talking with the non-human robot, CommU. Historically, Japan has a culture of shame (Benedict, 1946; Kato et al., 2012, 2019). All participants in this study were Japanese, which may have enhanced the shame-related actions. The participants especially MDD patients may have felt less shame for the robot interviews than for the human interviews. On the other hand, shame-related issues are not limited to Japan. Previous studies in other counties have shown a strong association between depressive symptoms and shame consciousness in patients with depression (Andrews and Hunter, 1997; Cheung et al., 2004; Kim et al., 2011; Orth et al., 2006; Wright et al., 1989). Therefore, understanding depressive symptoms requires understanding shame consciousness.

Why did MDD patients feel more comfortable talking to the robot, while HC participants' impressions did not change in this study? Patients with depression are known to hide or mend their symptoms (Kato et al., 2016). In the post-interview comments, participants in both groups commented that in human interviews, they sometimes mend their inner voices because they are concerned about how others will think of them. With robots, they can speak without worring about the other person's verbal and non-verbal complex reactions because robots do not show human-like reactions. Patients with depression are hesitant to talk about their own symptoms because they are afraid of others' reactions. When talking about a robot, patients may have less caution about the reactions of others. The present results suggest that patients with depression may be much more concerned about the reactions of those whom often communicate with.

What is the significance of utilizing communication robots for psychiatric interviews instead of classical/standard human interviews? A robot can perform instructed tasks consistently regardless of types and characteristics of the facing persons, time, or location. In other words, the standardization and reproducibility of tasks could be easily ensured. For example, using a non-human medium, such as a robot, allows for a more standardized and reproducible evaluation (Scassellati, 2007). In psychiatric practice, evaluations are primarily based on the subjectivity of the evaluator. As an evaluator, a robot can generate questions and evaluate responses without bias. In addition, Baba et al. reported that compared to face-to-face communication, robot operators deal with a lighter workload and consequently can handle longer hours with robot-mediated communication. At the same time, they reported that robot-mediated communication possibly adds less emotional stress on customers (Baba et al., 2021).Furthermore, robots do not become tired or fatigued. The medical field is constantly suffering from a lack of human resources. Therefore, future robots may perform many kinds of interviews for 24 h with the same or advanced quality compared to humans when equipped with AI technology. By applying assistant robots in future clinical practices, doctors, psychologists, and other medical staff will be able to focus on areas that require human judgment (Pennisi et al., 2016).

The present tele-operated system we adopted, in which the psychiatrist in the next room remotely operated the robot. The effort to operate the system is almost much the same as regular human interviews. With the development of AI technology, AI and self-capacities robots will be a more powerful solution to spread the AI-operated robot system which can assess patients with depression. However, no such robot has been developed in this time. Even though such robots have been developed, some people may reject the robot interview because of the appearance of robots or the fact that robots conduct interviews. Other people may have more favorable impression of the robots than human. Therefore, these impressions are crucial for widespread adoption of such robots. The present findings suggest that impression of robots at least CommU are positively evaluated by users especially during interviews about shame-related issues.

On the other hands, during the COVID-19 pandemic, physical distance has been forced to be maintained, and in-person mental healthcare settings are facing many difficulties (Do Duy et al., 2020; Kato et al., 2020; Kuki et al., 2021; Muhidin et al., 2020; Pignon et al., 2020; Sun et al., 2020). Thus, robot interviews have merits to minimize the risk of infection. Furthermore, since robot interviews are direct, robot interviews will provide a sense of being "treated here and now," which is not possible with telemedicine. Indeed, robot interviews are more effective when physical interaction between the robot and the participant is involved than remotely conducted. Even in robot technology, Li et al. point out that the presence factor is likely to influence user responses (Li, 2015). In this study, direct communication with the robot might have helped a positive change in MDD patients.

5. Limitation

There are some limitations to this study. A small sample size (13 MDD patients and 27 controls) limits the generalizability of the results. In addition, our human evaluator being male-only may have introduced gender bias. Depression manifestation and societal stigma can vary across genders. Therefore, having evaluators of various genders would have offered a more comprehensive perspective. To combat these limitations, future investigation with much more sample size and with evaluators of various genders should be conducted. Furthermore, the participants in this study were only Japanese. Further studies with a larger number of participants, raters, and other countries are desirable. The attitudes of healthy control participants towards the robot did not change over the course of the study. This result might be caused the fact that all participants were recruited from the same university campus. Thus, recruitment of participants should be conducted in various places. Another limitation is that we included fewer individuals with moderately-severe MDD, who may have different reaction and impression towards robots. Thus future study should include individuals with such patients. Severity of depression (i.e. HDRS score) may vary from day to day, thus we conducted the robot and human interviews on the same day. However, this same-day interview method may have led some participants to guess the study purpose. The present study touches upon the topic of tele-operated humanoid robot's efficacy using the HDRS semi-structured interviews, however this study doesn't provide the details on the depth of the interviews. Further research is desired to reveal the depth of robot interviews. The long-term implications of using robots for interviews are also needed. Follow-up studies are crucial to reveal whether patients' comfort with robots remains consistent over time or changes as they get used to the technology. Factors such as cultural background, previous experiences with technology, or even individual personalities could play a significant role in the present results. Future studies could delve deeper into these aspects, perhaps by considering a more diverse demographic or by exploring underlying reasons through qualitative interviews.

6. Conclusion

The present study has revealed that robot interviews for assessing the severity of depression are potentially equally reliable as human interviews. We have also shown that robot interviews are more likely to reduce hesitation to disclose inner feelings especially in questions related to shame consciousness. We believe that applying robot interviews in clinical practice will reduce the stigma and self-stigma associated with depression. Furthermore, when combined with AI technology, robot interviews would reduce the mental and physical burden on patients and healthcare providers. These situations will become more pronounced when we reach the stage where psychiatric evaluations are performed using AI technology.

Author statement

T.A.K. contributed to the conception and design. T.A.K. and T.M. were responsible for protocol of the investigation. T.M., K.M., K.K., and T.A.K. contributed to the clinical data collection. Y.Y., Y.U., H.I. contributed to robotic technology. T.M., Y.Y., K.M., H.K., and T.A.K. contributed to the data checking, analysis, and interpretation of data. T. M. drafted the manuscript, and Y.Y., K.M., T.N., H.K., and T.A.K. revised it critically for important intellectual content. All authors have provided final approval of the version to be published.

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Declaration of competing interest

All the authors declare no conflict of interest.

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This study was approved by the Ethics Committees of Kyushu University. This manuscript was edited by a native English speaker, Ms. Monica Natsumi Daudelin.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpsychires.2023.12.014.

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