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在宅高齢者を対象とした「こころ」の見守りサービスの運用と品質評価

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あらまし　高齢者の在宅での自立生活を支援するためには，高齢者の自助機能を高めることに加え，高齢者の心の状態まで考慮した支援が必要である．しかしながら，人手による聞き取りや既存見守りサービスの限界，毎日の心理状態の記録や自発的な外化が難しいという問題がある．こうした問題を解決するため，先行研究では，在宅高齢者を対象とし，心理状態の見守りと自発的なメンタルヘルスケアを促すことを目的とした「こころ」の見守りサービスを提案している．提案サービスでは，チャットボットが高齢者に対し，心理状態の取得に特化した問いかけを継続的に行う．その回答に基づき，サービスは対象者の心を見守り支援へつなげる．本稿では，実装した提案サービスを実際の世帯に対して適用し，サービスを実運用する．またソフトウェアの品質評価規格である SQuaRE に基き，提案サービスを評価する．運用の結果，長期間の被験者の心理状態データを取得することができ，提案サービスの効率性が確認された．
キーワード　在宅介護，高齢者見守りシステム，心理状態，センシング，エージェント，チャットボット

Operation and Quality Evaluation of Mind Monitoring Service for Elderly People at Home

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Abstract　In order to support sustainable in-home long-term care, it is essential to monitor mental states of elderly people at home, and to encourage their ability of self-care. However, many challenges exist in practice, including limitations of human interventions, sensor-based monitoring, as well as the daily recording and externalization of mental states. In the previous research, we have proposed *Mind Monitoring Service*, which aims to monitor mental states and promote self-care of elderly people at home. In the proposed service, a chatbot asks a user specific questions to acquire his/her mental state. Based on the answers, the service then assesses the mental state and sends the feedback. In this paper, we apply the proposed service to actual households and operate the service. In addition, we evaluate the service based on SQuaRE, which is the international standards to evaluate the implementation of software. As a result, we were able to obtain long-term mental states data of the subjects and to confirm the efficiency of the proposed service.
Key words　in-home long-term care, elderly monitoring system, mental state, sensing, agent, chatbot

1. Introduction

Currently, Japan is facing a super-aging society. The proportion of people over 65 years old in the total Japanese population was less than 5% in 1950, but it increased to 28.4% in 2019 [1]. Under these circumstances, there are chronic shortage of nursing facilities and care workers. To cope with the problem, the Japanese government is shifting the policy from the conventional facility-based care into the *in-home long-term care*. The Ministry of Health, Labor and Welfare in Japan declares the *Community-based Integrated Care System* [2], which ensures the provision of health care, nursing care, prevention, housing, and livelihood support. The system consists of four

principles: self-care, mutual care, public support, governmental aid. Due to the limitation of the security cost, the government especially expects elderly people to conduct the self-care under the system.

However, the self-care and independent living are not easy for most elderly people, as their physical abilities and cognitive functions are being declined. Moreover, elderly people have higher risk of mental depression, compared to those of younger ages due to their *loss experiences* [3]. Taking these facts into consideration, in the in-home long-term care, it is essential to monitor their *"mind"* and to provide appropriate supports according to the state of the "mind".

In monitoring the psychological aspects of elderly people at home, we consider the following three challenges:

(P1)Limitations on human interventions and sensor-based monitoring : Traditionally, the mental states of elderly people have been assessed via human intervention such as inquiries and counseling by professionals. However, it is not realistic to conduct such interventions every day at home. Recently, the elderly monitoring systems using sensors and IoT come onto markets. However, they can only monitor externally observable events. Thus, the conventional monitoring systems do not cover internal mental states of elderly people.

(P2)Challenge in recording and externalizing mental state : Every mental illness of an elderly person (e.g., depression) is caused by various factors. The symptoms also vary from one person to another [4]. Thereby, to specify the mental illness is not easy. Furthermore, the elderly also cannot grasp their own mental states accurately and externalize the states.

(P3)Challenge in realizing mind monitoring and appropriate support based on the mental state : Considering (P1) and (P2), it is difficult for any third person to objectively grasp, record and monitor the mental states of elderly people at home. The elderly also have no opportunity to reflect on their mental states. Therefore, it is yet challenging to support elderly people based on their internal mental states.

To overcome these challenges, in this research, we have proposed *Mind Monitoring Service* [5]. In this service, we firstly introduce a continuous interaction platform between an elderly person and a chatbot. Secondly, the chatbot asks various questions to acquire the mental state. Finally, the service evaluates the "mind" of an elderly person based on the answers to the questions and realizes "mind" monitoring.

In the previous research [6] [7], we have implemented the proposed service. In this paper, we apply the implemented proposed service to actual households and operate the service. We also evaluate the service from the viewpoint of *SQuaRE (Systems and software Quality Requirements and Evaluation)* [8], which is one of the international standards to evaluate the implementation of systems or software.

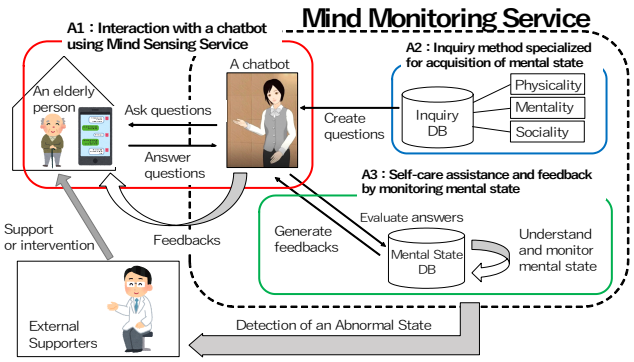

図 1　Overall Architecture

2. Mind Monitoring Service [5] [6] [7]

2.1 System Architecture

The Mind Monitoring Service is a new ICT service which evaluates and monitors the mental state of an elderly person via communication with a chatbot. Figure 1 shows the overall architecture of the proposed service. The service consists of the following three approaches (A1) to (A3).

(A1) Interaction with a chatbot using Mind Sensing Service : The *Mind Sensing* (「kokoro」 sensing in Japanese) is a new type of sensing technique being developed by our research group [9]. It aims to record the internal mind of a target person that cannot be observed externally by general sensors or IoT. In the Mind Sensing, a virtual agent (VA) [10] or a chatbot asks the person various questions to externalize his/her mind as words. The *Mind Sensing Service* [11] is a core Web service of the Mind Sensing, which defines and manages the questions flexibly, and automates the delivery of the questions. The proposed service utilizes the Mind Sensing Service and collects internal states through interaction with a chatbot.

(A2) Inquiry method specialized for acquisition of mental state : In order to understand mental states of elderly people at home, we develop specific questions. For this purpose, we firstly introduce a framework characterizing mental health using three perspectives: *Physicality*, *Mentality*, and *Sociality*. Physicality evaluates the physical symptoms that can be seen objectively, such as fatigue, pain, sleep disorders. Mentality evaluates the subjective feelings such as emotions, moods, stress. Sociality evaluates the self-evaluations or behaviors of a target person, such as happiness, self-esteem, and social behavior. These three perspectives are taken by WHO's "health" definition [12]. Secondly, we create inquiries that reveal the current state for each of the three perspectives. We assume the target elderly person answers the questions with yes or no. The chatbot in (A1) asks these questions to an elderly person, and the service then records his/her answers to grasp the mental state.

(A3) Self-care assistance and feedback by monitoring mental state : By collecting the answers to the questions, the service evaluates the mental state of an elderly person. For this purpose, the service calculates *the degree of psychological health* by assigning

表 1　Seven Questions

Question	Survey Item	Category
Have you slept well in the past week?	Sleep	Physicality
Have you felt sick, pain, or tired during the past week?	Health	Physicality
Have you had something fun in the past week?	Emotion	Mentality
Have you felt you could not remember something, or forgotten something in the past week?	Memory	Mentality
Have you felt anxiety or unwell during the past week?	Psychology	Mentality
Have you felt not motivated or appetite in the past week?	Motivation	Sociality
Have you had many opportunities to go out, to talk and to have hobbies in the past week?	Socialization	Sociality

the score to the answers. Analyzing the changes of the scores on a weekly or monthly basis enables the proposed service to monitor the mental state of the target person. Also, the service gives feedbacks based on the acquired mental states, in order to encourage self-reflection and spontaneous self-care of mental health. Furthermore, if an abnormal state which cannot be solved by self-care is detected, the service connects to an external supporter, and asks for appropriate instructions.

2. 2　Implementation of Chatbot Interaction

In [6], we have mainly implemented the chatbot interaction of the service. We firstly asked an expert to create seven questions which will be sent to users. Table 1 shows the questions. These questions ask the state of the past one week. "Survey item" in Table 1 indicates what to investigate by the question. In addition, "Category" in the Table 1 shows the results of classifying each question into the three perspectives described in **2. 1** (A2). Secondly, we built a continuous interaction between an elderly person and a chatbot, using LINE [13] which is a well-known messaging application on smartphone. The chatbot sends one question in Table 1 once a day to the user. The user answers the question with two choices, yes or no. All of the seven questions can be covered in a week, so the chatbot sends the first question again from the next week. In other words, the chatbot will continue to send the same set of questions each week.

Figure 2 shows the actual screen of the proposed service implemented on LINE. The user can answer the question from the chatbot just by pushing the button of the screen. When the user answers the question, the chatbot sends an additional question for the purpose of investigating the user's situation in more detail. For example, Figure 2 shows the case where the user answers "Yes, I've slept well." to the question, "Have you slept well in the past week?" After understanding a good sleep condition of the user, the chatbot sends an additional question to ask any concerns regarding sleep. The user then answers the additional question by inputting text messages.

2. 3　Implementation of Self-care Assistance

In [7], we have developed scoring methods for evaluating mental states, and a feature of weekly feedback for promoting spontaneous mental health care. As for the scoring methods, we introduced the

図 2　Actual LINE Screen

following three scoring methods for assigning scores to the answers.

(i) Score_answer : The binary score of the answer. We assign 1 points for a positive answer and -1 points for a negative answer.

(ii) Score_observation : The score obtained by observing how the answer has changed from the previous week. For example, when the user answered positively in the previous week, if the answer remains positive in the target week, 1 points will be assigned to the answer. If the answer turns negative, -0.5 points will be assigned.

(iii) Score_sentiment : The analytic score of sentiment for the user's answers to an additional question from a chatbot. If the user answers the additional question after answering the first yes-no question, the service analyzes the text and calculates the sentiment.

The total score of the answer is calculated as the average of the three scores. By aggregating these scores for each of the three categories described in **2. 1** (A2), the service grasps and visualizes the degree of psychological health of the user.

About self-care assistance, we developed a new feature of weekly feedback. In the feedback, the service selects one question whose score is the worst in a week. Then, the service creates a feedback message that presents the user's past states and gives advices to improve the current situation. Figure 3 shows an example of a feedback message. In this feedback, the question about "psychology" was picked up. The chatbot indicates that the user said she had been feeling anxiety before, and suggests that she should have her family or friends listen to her anxiety. By receiving such feedback on a weekly basis, users can periodically reflect on their mental states. The service can also promote the user's self-care consciousness.

3.　Operating Mind Monitoring Service

3. 1　Outline of Operation

The operation period was from November 1, 2019 to January 31, 2021, one year and two months (14 months) in total. During this period, in addition to 8 elderly subjects (in the 50s to 80s), we also had 19 men and women in the 20s to 40s use the service continu-

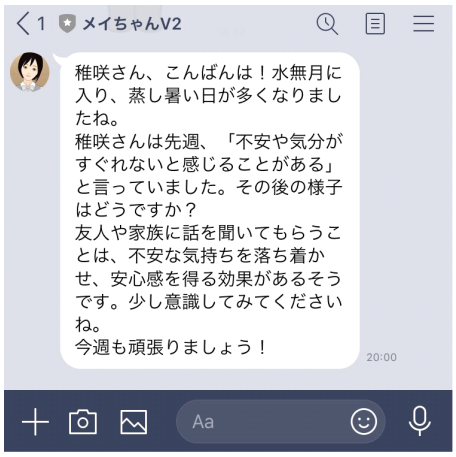

図 3　Example of a Feedback Message

ously. Although the proposed service was originally intended for the elderly generation, we also recruited young subjects in order to evaluate the effectiveness of the proposed service itself. During the operation, if the subject feels any burden, the person can quit answering questions from the chatbot at any time. Besides, we explained to the subjects that the logs of their interactions with the chatbot would be stored in our database, and would not be disclosed to any third party except the experiment administrators.

These studies have been approved by the research ethics committee of Graduate School of System Informatics, Kobe University (No. R01-02). Written informed consent was obtained from subjects for publication of this thesis and accompanying images.

3.2 Responsiveness and Continuity

As a result of the operation, two elderly subjects stopped using the service within a few months. About one of the two elderly (male in the 70s), it was difficult for him to use the service because he did not use his smartphone frequently in his daily life. The other elderly person (male in his 70s) had been using the service for the first three months, but he eventually stopped using it because his asthma worsened, and made him difficult to continue to answer the questions from a chatbot every day. For the remaining 25 subjects, we were able to get them to use the proposed service continuously. We especially show the response rates of elderly subjects for the entire 14-month in Table 2. The response rate is calculated by the ratio of the number of questions answered by the subject to the number of questions sent by the chatbot.

表 2　Total Response Rate of Elderly Subject

Subject	Age	Gender	Rate
A	70〜79	M	91%
B	60〜69	M	92%
C	80〜89	F	30%
D	70〜79	F	90%
E	70〜79	F	54%
F	50〜59	F	95%

From Table 2, we can see four out of six elderly subjects responded to more than 90% of the questions from a chatbot. For subject C and E, the overall response rate was low, not because they had stopped using the service, but simply because they responded less frequently. Regarding the other 19 subjects (in the 20s to 40s), the response rates averaged 80%. Considering these results, it was confirmed that the responsiveness and continuity of the service were generally good.

3.3 Analyzing Fluctuation of Mental State

Through 14 months of the operation, the service obtained a large amount of mental state data. Figure 4 shows the graph of the mental state scores of subject A (male in 70s) in 2020. In the graph, the vertical axis represents the average score value and the horizontal axis represents months.

In Figure 4, we can firstly confirm that subject A's scores of each perspective are generally positive. This means his condition is relatively stable throughout the year, and his mental health in terms of Physical, Mental and Social is maintained to some extent. However, we can see that his Physicality score dropped sharply in the middle of May. When we asked subject A about the reason, he said that he had hurt his leg by walking too much at that time. Afterwards, thanks to treatment and rehabilitation, his leg finally started to get better around July. Also, we can find that his Sociality score dropped in early March. This was because the spread of the coronavirus (covid-19) reduced his opportunities to go out. For a while after that, he stopped exercising at the gym, and his Sociality score continued to stagnate. However, he started to go to the gym again around October, and his Sociality score started to increase.

4. Investigation of Quality in Use

4.1 Evaluation Method

In this section, we discuss the quality of the Mind Monitoring Service based on the opinions of the subjects.

After the long-term operation, we evaluated the proposed service from the viewpoint of *SQuaRE* [8]. SQuaRE represents one of the international standards ("ISO/IEC 25000 Series") which indicates the line of thinking for the stakeholders to define various quality requirements and to evaluate the implementation of systems or software. SQuaRE defines the quality characteristics from three perspectives (*Product Quality*, *Data Quality*, *Quality in Use*) to build a quality model of the system. In this paper, we especially use the Quality in Use Model that evaluate the degree to which the user can use the system in a certain usage situation comparing with the user's needs. The Quality in Use Model is defined by five quality characteristics and eleven sub-characteristics (Figure 5). Since the quality in use is evaluated through user usage, we created a questionnaire to evaluate all of the quality characteristics and sub-characteristics.

4.2 Results of Questionnaire

In this paper, we especially discuss the quality characteristics of *Effectiveness, Efficiency, Usefulness, Comfort* and *Flexibility*. Figure 6 shows the questions and results of the questionnaire regarding above characteristics. In each question, our proposed service is

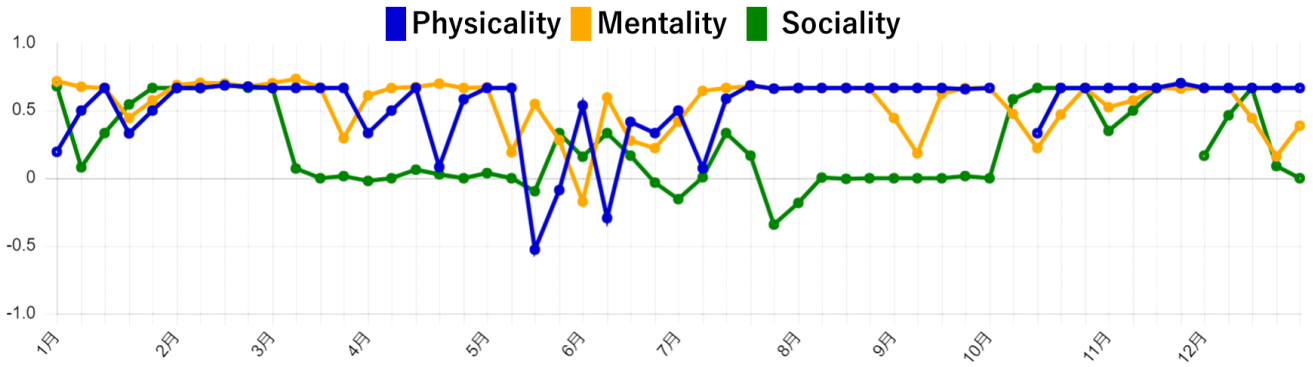

図 4　Mental Sate of Subject A

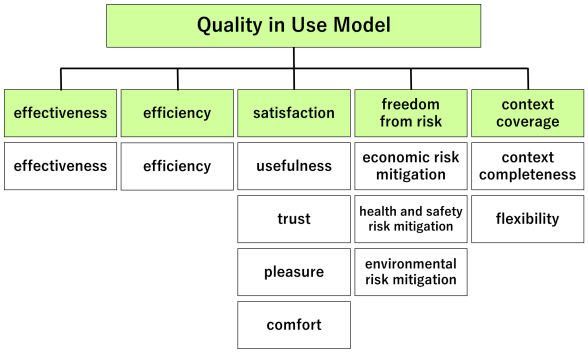

図 5　Quality in Use Model

Question		Strongly Agree	Agree	Disagree	Strongly Disagree
Q1	Do you think you were able to reflect on your mental state through the interaction with Mei-chan?	27.8%	50.0%	16.7%	5.6%
Q2	Do you think the interaction with Mei-chan helped you to learn about your condition and to improve it?	5.6%	55.6%	33.3%	5.6%
Q3	Do you think the daily interaction with Mei-chan was laborious and difficult?	0%	27.8%	27.8%	44.4%
Q4	Do you think it was difficult to answer Mei-chan's questions because they were so frequent?	0%	11.1%	27.8%	61.1%
Q5	Do you think the interaction with Mei-chan was useful to reflect on your mental state?	16.7%	50.0%	33.3%	0%
Q6	Do you want to continue to use this service?	33.3%	38.9%	16.7%	11.1%
Q7	Do you think it was easy for you to interact with Mei-chan?	72.2%	22.2%	5.6%	0%
Q8	Do you think you were able to check your mental state easily by interacting with Mei-chan?	33.3%	61.1%	5.6%	0%
Q9	Mei-chan can record the data even if you enter the answers at a later time in batches. Did you do this way of answering?	33.3%	11.1%	11.1%	44.4%
Q10	Do you think the flexibility, for example, the service does not require to respond immediately as in Q9, is important?	61.1%	33.3%	5.6%	0%

図 6　Results of Questionnaire

named *Mei-chan*, which is the display name of the LINE chatbot. The questionnaire was answered by 18 subjects.

Effectiveness

Effectiveness means the degree of accuracy and completeness with which the user achieves the stated goals. Thus, the effectiveness of the proposed service can be assessed by whether the users were able to reflect on their own state and achieve spontaneous mental health care. From Q1, we can see that most of the subjects were able to reflect on their own states. However, Q2 shows that the subjects could not make much efforts to improve their mental states. Thereby, although we were able to confirm the effectiveness of the service to some extent, it was not sufficient.

Efficiency

Efficiency means the degree of the resources used by a user for achieving a particular goal, so the efficiency of the proposed service can be evaluated by the ease of interacting with a chatbot. From Q3 and Q4, it can be seen that interacting with the chatbot was not laborious, nor difficult to answer questions in terms of frequency. Therefore, the efficiency of the service was confirmed.

Usefulness

Usefulness means the degree of user satisfaction. Therefore, the usefulness can be measured by how much the user finds the service useful. From Q5, more than half of the subjects answered that interacting with the chatbot was useful for reflecting on their own states, while nearly 30% did not. Besides, since it was revealed that some subjects did not want to continue to use the service in Q6, we could not confirm the usefulness of the service very well.

Comfort

Comfort means the degree of user satisfaction with comfort when using the system or software. Thus, the comfort can be evaluated by the ease of using the service including the operability. Since Q7 and Q8 show that the subjects were able to interact with the chatbot and reflect on their own conditions easily, we can confirm the comfort of the proposed service.

Flexibility

Flexibility means the degree to which a product or system can maintain the quality even in a unexpected usage situation. In the proposed service, users are expected to answer one question from a chatbot every day. However, from Q9, we found there were some cases where the subjects entered their answers at a later time in batches. Although these cases were not originally intended, the fact that there was no problem in using the service suggests that the ser-

vice maintained a certain degree of flexibility. In addition, in Q10, the subjects said that this kind of flexibility was important.

4.3 Discussion

Based on the results of operation and questionnaire of quality in use, we can discuss if the purpose of the proposed service has been achieved. The purpose of this service can be roughly divided into following two, *visualization and monitoring of mental states* and *promotion of spontaneous mental health care*.

As for visualization and monitoring of mental state, since we were able to acquire mental state data for more than one year, we believe this purpose has been achieved. In particular, it is noteworthy that we were able to continuously acquire mental state data during such a long period. We consider this is because that the efficiency and flexibility of the service had a positive impact on the subjects' continuity. Namely, the facts that it was easy for the subjects to interact with a chatbot and that they were able to use the service whenever they wanted may have promoted the continuity of service use.

On the other hand, promotion of spontaneous mental health care has not been achieved, considering the results of the questionnaire. We thought that reflecting on one's own condition would lead to self-care, but in fact, although the subjects were able to reflect on their own states, they could not achieve improvements or self-care. One possible reason for this is the differences of interests in health of the subjects. We applied the service to 27 subjects in total, but each subject has a different health consciousness. In particular, since many of the subjects were relatively young, it is likely that the majority of the subjects did not feel any anxiety or problem about their own health. Therefore, they may have felt there is no need for improvement and have failed to achieve self-care.

Also, as revealed in the questionnaire, the usefulness of the service was also insufficient. Moreover, we obtained comments from the subjects such as "I felt that chatbot's replies were like fixed form sentences." or "I felt a little stressed to be asked the same question every week." In order to encourage the users to conduct spontaneous self-care and to perceive the usefulness of the service, it will be necessary to prevent the users from becoming accustomed to interacting with a chatbot. We would like to devise methods not to make users feel boring including to change questions or to provide interesting information for users, as a future work.

5. Conclusion

In this paper, we operated the Mind Monitoring Service to actual households. We also evaluated the effectiveness and quality in use of the service based on the viewpoint of SQuaRE. The results show that while the service was able to obtain long-term mental state data of the subjects, the usefulness of the service was still insufficient.

As a future work, we would like to devise more efficient methods for monitoring mental states of elderly people at home, and encouraging them to conduct self-care. Furthermore, we would like to have more elderly people use the proposed service in order to further develop the service.

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