

Prototyping and Preliminary Evaluation of Mind Monitoring Service for Elderly People at Home

Chisaki Miura¹, Haruhisa Maeda¹, Sachio Saiki¹, Masahide Nakamura^{1,3}, Kiyoshi Yasuda²

¹Graduate School of System Informatics, Kobe University, Japan

²Riken AIP, Tokyo

³Faculty of Informatics, Osaka Institute of Technology, Japan

cmiura@ws.cs.kobe-u.ac.jp, haruhisa@ws.cs.kobe-u.ac.jp, sachio@carp.kobe-u.ac.jp

masa-n@cs.kobe-u.ac.jp, fwk5911@mb.infoweb.ne.jp

ABSTRACT

In order to support sustainable in-home long-term care, it is essential to monitor mental states of elderly people at home, as well as to encourage their ability of self-care. However, the technical challenges include the limitations on human interventions and sensor-based monitoring, as well as daily recording and externalization of mental states. In this research, we propose Mind Monitoring Service, which aims to monitor mental states and promote self-care of elderly people at home. In the proposed service, an agent asks a user specific questions to acquire his/her mental state. Based on the answers, the service then assesses the mental state and sends feedback. We implement a prototype service, and evaluate the feasibility of the service through a preliminary experiment. The results show that data characterizing mental states of individual subjects was obtained successfully, and that some subjects externalized their minds by feedback from the service.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **Ubiquitous and mobile computing systems and tools**; • **Applied computing** → **Health care information systems**.

KEYWORDS

in-home long-term care, elderly monitoring system, mental state, sensing, agent, chatbot

ACM Reference Format:

Chisaki Miura¹, Haruhisa Maeda¹, Sachio Saiki¹, Masahide Nakamura^{1,3}, Kiyoshi Yasuda². 2019. Prototyping and Preliminary Evaluation of Mind Monitoring Service for Elderly People at Home. In *The 21st International Conference on Information Integration and Web-based Applications & Services (iiWAS2019)*, December 2–4, 2019, Munich, Germany. ACM, New York, NY, USA, 7 pages. <https://doi.org/10.1145/3366030.3366127>

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

iiWAS2019, December 2–4, 2019, Munich, Germany

© 2019 Association for Computing Machinery.

ACM ISBN 978-1-4503-7179-7/19/12.

<https://doi.org/10.1145/3366030.3366127>

1 INTRODUCTION

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 28.1% in 2018[3]. 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*[12], which ensures the provision of health care, nursing care, prevention, housing, and livelihood support by the year 2025. 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. Thus, some external supports must be needed. Moreover, elderly people have higher risk of *mental depression*, compared to those of younger ages due to their lost experiences [11]. 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 [10]. Thereby, the mental illness is often mistaken as just the aging phenomenon or poor physical condition. Furthermore, without any opportunity, elderly people would not spontaneously externalize their mental states into words or written sentences.

(P3) Challenge in realizing mind monitoring and appropriate support based on the mental state: As a result of (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 their mental states. Therefore, it is yet challenging to support elderly people based on their internal mental state.

To overcome these challenges, we propose *Mind Monitoring Service* in this paper. For elderly people at home, the proposed service aims to monitor their mental states, as well as to promote self-care based on the states. More superficially, we tackle the above challenges (P1) to (P3) by the following (A1) to (A3), respectively.

(A1) Interaction using Mind Sensing Service: Our research group has been studying *Mind Sensing*. In the *Mind Sensing*, a virtual agent (VA) autonomously talks to a target person, triggered by an environment/behavior sensing as well as the time schedule. The target then answers the question and the system records the answer. This process externalizes his/her internal mind at that time as words [7][4]. The *Mind Sensing Service* is a core service of the *Mind Sensing*, by which a user can define the questions from the VA systematically and flexibly. In this research, we extensively utilize the *Mind Sensing Service* to acquire the mental state of the elderly via the interaction between VA and elderly people.

(A2) Inquiry method specialized for acquisition of mental state: We propose an inquiry method specific for acquiring mental states of elderly people. Based on mental tests and counseling techniques in the clinical psychology, we develop questions that can be easily answered by the elderly. As the VA in (A1) asks these questions, the target person responds to them and externalizes the current mental state. Repeating this process, the proposed service records the mental states of the elderly people at home, continuously.

(A3) Self-care assistance by monitoring and feedback of mental state: The answers to the questions are aggregated on a weekly basis to observe the mental states. Depending on the observation, the proposed service creates feedback to the target person, including further questions and advice. The feedback makes the target person recognize his/her own mental state, and encourages the self-care. Moreover, if an abnormal state is detected, the service connects to external supporters and asks for appropriate instructions.

Thus, the proposed service is able to acquire mental states of elderly people at home continuously, which has been difficult so far. It can also provide monitoring and self-care of “mind”, with appropriate interventions based on the acquired mental states.

In this paper, we implement a prototype of the proposed service, and perform a preliminary experiment. Through the experiment, we investigate the practical feasibility and implementation issues of the proposed service.

2 PRELIMINARIES

2.1 Concepts of Health and Disease

The World Health Organization (WHO) defines the concept of *health* as follows [13]:

Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.

According to this definition, health is a *state* that can be characterized by three aspects: *physical*, *mental* and *social* aspects.

On the other hand, there are various ways of defining *disease*. A medical anthropologist, Young [14], classified the concept of *disease* into the following three types: *Disease* is an impairment that can be judged objectively. *Illness* is a disorder that is perceived subjectively. *Sickness* is used as a broad meaning including *disease* and *illness*, and is also considered as a state that the person cannot accomplish the social role completely.

2.2 Mental Illness of Elderly people

Typical mental illnesses elderly people tend to develop include *depression* and *anxiety disorder*. Depression is a psychiatric disorder that causes a variety of mental and physical symptoms, such as a strong depressive mood, loss of interest or pleasure and disorders of appetite and sleep [11]. Anxiety disorder is a mental illness that causes excessive anxiety, restlessness and the loss of concentration [10]. A major factor that causes the elderly to suffer from such mental illnesses lies in their *experiences of loss*. The experiences include the deterioration of physical ability due to aging, the loss of social role by the retirement, and the bereavement of familiar people [10].

Moreover, it is often difficult to detect the mental illness of elderly people. For example, since elderly people with depression tend to be less expressive, their sorrow, bad moods, and thought of depression are not well observed. Thus, the depression of elderly may be overlooked by a regular diagnostic criteria [11]. Similarly, the symptoms of general anxiety disorder, such as being tired, lack of concentration, and sleeping disorder are commonly observed among elderly people. Therefore, the mental illness of elderly should be treated comprehensively by various factors including changes of daily thinking and physical declines.

2.3 Psychological Assessment Tools

Unlike physical illness which causes symptoms on specific parts of the body, mental illness causes global disorders in thought, consciousness, and physics. Hence, it is necessary to grasp the state of the person from various viewpoints. The *psychological assessment tools*, including tests, scales, and questionnaires, are tools to quickly assess the mental state of the person.

A *questionnaire sheet* consists of multiple questions, each of which the subject writes the answer for. To avoid burdening the subject, every question is generally written in short and simple sentences. The subject answers the question with Yes and No, or chooses one from multiple scale. Representative questionnaires for psychological assessment include, GDS-15 (Geriatric depression scale 15) [9]: the depression scale for the elderly, PHQ-9 (Patient Health

Questionnaire-9) [6]: assessment of general depression, GAD-7 (Generalized Anxiety Disorder-7) [6]: measuring the degree of anxiety disorder, and GHQ (General Health Questionnaire) [2]: assessment of nephropathy. Although these questionnaires are not directly used for diagnose, they are widely used for the screening purpose, assessing the degree of symptoms and signs.

2.4 Mind Sensing Service [5]

The *Mind Sensing* (“kokoro” sensing in Japanese) [7][4] is a new type of sensing technique being developed by our research group. 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) or *chatbot* asks the person various questions to *externalize* his/her mind as words. The *Mind Sensing Service* [5] is a core service of the Mind Sensing, which defines and manages the questions, and automates the delivery of the questions and the collection of the answers.

The Mind Sensing Service mainly consists of two parts: *actions* and *rules*. An *action* defines a delivery of a concrete message to users, which is specified by three items: target person(s) to which the message is sent, the body of the message, and a service to deliver the message. The services currently implemented include VA (a virtual agent [8] on user’s PC), LINE (a dedicated LINE chatbot [1] on user’s smartphone), and MAIL (user’s email). For example, suppose that we want to implement an action where the LINE chatbot asks a user A “How are you feeling now?”. Then, we define an action: `act1 = {targets: ["A"], messagebody: "How are you now?", service: "LINE"}`.

A *rule* defines a trigger to execute actions, which is typed by either time-based or event-based. A *time-based rule* repeatedly executes actions at the designated time and time interval. It is specified by actions to be executed, the start time, the end time, and the time interval by minutes. For example, suppose that we want to execute the above action act1 every two hours from 8 o’clock to 20 o’clock. Then, we define a time-based rule: `rule1 = {actions: ["act1"], since: "8:00", until: "20:00", interval: 120}`.

An *event-based rule* triggers actions by an event input from an external system. It is specified by actions to be executed, an enabling condition over the event, and the cooling time to the next execution. For example, we can define an event-based rule like: the VA says “Good morning! Did you sleep well?” when a behavior recognition system detects that user A wakes up in a bedroom between 7 o’clock and 8 o’clock in the morning. Then, we create an event-based rule: `rule2 = {actions: ["act2"], since: "7:00", until: "8:00", location: "bedroom", event: "behavior recognition .WAKEUP", cooling: 60}, where act2 = {targets: ["A"], messagebody: "Good morning! Did you sleep well?", service: "VA"}`.

3 PROPOSED METHOD

3.1 System Architecture

Figure 1 shows the overall system architecture of the *Mind Monitoring Service*. As seen in the figure, the proposed service consists of three parts. They achieve the three approaches (A1) to (A3) described in Section 1, respectively.

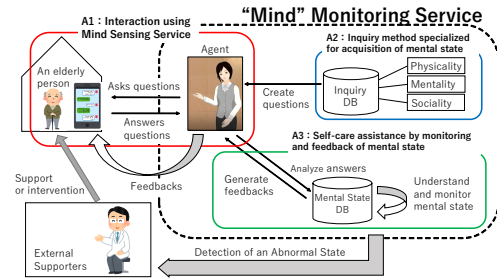


Figure 1: System Architecture

- (A1) **Interaction using Mind Sensing Service:** Using the Mind Sensing Service, the proposed service periodically collects internal states of an elderly person at home, through interaction between the agent and the person.
- (A2) **Inquiry method specialized for acquisition of mental state:** We develop inquiries specific for acquiring mental states of the elderly person. The inquiries are stored in a database. The inquiries are then encoded by actions and rules of the Mind Sensing Service.
- (A3) **Self-care assistance by monitoring and feedback of mental state:** Every time the elderly person answers a question, the answer is stored in a database with timestamp. With an appropriate period, the service then analyzes the collected mental states. According to the result, the service produces feedback including further questions and advise. If an abnormal state is detected, the service connects to external supporters, and asks for appropriate instructions.

3.2 A1: Interaction using Mind Sensing Service

By using the Mind Sensing Service, the agents (i.e., a VA or a chatbot) can listen to and record the internal minds of elderly people, instead of human caregivers. In the proposed service, we let an agent send questions to elderly people at a fixed time every day. For this purpose, we apply the time-based rule of Mind Sensing Service. For the human-agent interaction, we use the LINE chatbot over a well-known messaging application on smartphone.

The reason why we chose the LINE chatbot as the interaction tool is that the chatbot is easier and more reliable to exchange the questions and the answers, compared to the VA on the PC or E-mail. The questions (described in detail in A2) for acquiring the mental states are somewhat technical. Thus, the text messages over the message chat is clearer than the voice dialogue with the VA. In addition, LINE has an intuitive UI and text input support with speech recognition. It is already accepted by many elderly people. Therefore, we consider that LINE is more suitable than e-mail.

3.3 A2: Inquiry Method Specialized for Acquisition of Mental State

In order to understand mental states of elderly people systematically, we first define a framework characterizing mental health. For this, we integrate the concepts of health and disease described

in Section 2.1, and characterize the mental health in the following three perspectives: *Physicality*, *Mentality*, and *Sociality*.

Physicality corresponds to the physical aspect of health and disease. It targets physical symptoms that can be explained by objective factors. In mental illness, such physical symptoms are quite important and should be assessed. In the physicality perspective, we try to grasp the mental health, according to the presence or absence of the physical symptoms.

Mentality corresponds to mental aspect of health and illness. It covers subjective feelings such as emotions and moods. Even with the same physical symptoms, the mental states of elderly people generally vary from one person to another. It is therefore essential to elicit a subjective sense through inquiries. In the mentality perspective, we characterize the mental health by subjective assessment.

Sociality corresponds to the social aspect of health and sickness. It covers the evaluation from others and self-evaluation. The evaluation from others means the state of the target person that can be pointed out by a third person. The self-evaluation means how the target person thinks himself (or herself). In general, the social health focuses on the evaluation from others only. However, in the psychological approach, the subject's self-awareness should also be considered. For example, a patient with depression often has a strong sense of guilty, and regards himself as a worthless person for no reason. Thus, it is crucial to ask how the subjects assesses themselves. Through the two types of evaluations, we try to grasp the mental health.

From each of the three perspectives, we develop inquiries that reveal the current mental state of elderly people. We create the questions within the inquiries by referring to the practical psychological assessment tools introduced in Section 2.3. For each question, we assume that the target elderly person answers by choosing one from four choices: "No, I do not think so at all", "No, I do not think so much", "Yes, somewhat I think so" and "Yes, I really think so". We intentionally omit a marginal choice "Yes or No", in order to encourage the target person to carefully reflect his/her current state.

To achieve sustainable and reasonable Mind Monitoring, we consider that the inquiries should be at most twice a day, and the number of questions in each inquiry should be at most three. Each inquiry is sent every day at a fixed time, considering the life rhythm of the target person. It is also necessary to change questions every day, and to send encouraging messages, so that the person does not get tired and quit answering.

We then encode the developed inquiries by actions and rules of the Mind Sensing Service. Finally, the Mind Sensing Service automatically sends the questions according to the specified rules, and collects the answers.

3.4 A3: Self-care Assistance by Monitoring and Feedback of Mental State

By analyzing the answers to the questions, the service grasps the mental state of the target person. As explained in A2, there are four choices for answering each question. We assign the score of 2, 1, -1, -2 to these choices, so that 2 points are for most healthy choice and -2 points are for most unhealthy choice. Each question

belongs to one of the three categories defined in A2. Therefore, the score of the response represents the degree of psychological health in the corresponding category. A positive score represents a healthy mental state, whereas a negative score represents a unhealthy mental state.

For example, let us consider a question "Do you often wake up while sleeping?" The question is classified in Physicality, as its intention is to examine the sleeping disorder. As for the four choices "No, I do not think so at all", "No, I do not think so much", "Yes, somewhat I think so" and "Yes, I really think so", score points 2, 1, -1, -2 are assigned to them, respectively. If the target person answers "Yes, I really think so", the current mental state of the Physicality perspective is evaluated to be -2 at this time.

The proposed service puts these scores in a time-series analysis, or statistically aggregates the scores on a weekly or monthly basis. Based on the analysis, the proposed service implements Mind Monitoring. The time-series analysis can detect *abnormal* mental states if the following observations are found: the negative scores last for a long time, the positive scores lasting for a long time suddenly changed to negative, or the target person suddenly quit answering.

The proposed service also generates *feedback* that encourages the target person to conduct self-care. The most basic feedback is to present problems or concerns that can be inferred from the answers. It also presents countermeasures to alleviate the situation. When the service detects an abnormal state that cannot be solved by self-care, it connects to external human caregivers to request human intervention or support.

For example, let us consider again the previous question, "Do you often wake up during the night?" The answer "Yes, I really think so" represents that the person may have sleep disorder. Then, the service makes a further question: "Recently, you may not sleep well. There may be suspicion of sleep disorder. Please let me know if you have any trouble or worry." On receiving such feedback, the person can recognize the possibility of sleep disorder, and reflect the cause of it. Besides, if the service tells countermeasures to alleviate sleep disorders, or introduces medical institutions, it is promising to reduce the subject's anxiety, significantly.

Operating the proposed service continuously enables the Mind Monitoring of elderly people at home. Based on the accumulated answers, statistics, and feedback, individual elderly people can reflect their minds by themselves. Also, the accumulated data can be used as strong evidence for *personalized* medical care and nursing, optimized for individual subjects.

4 PROTOTYPE IMPLEMENTATION

4.1 Configuring Mind Sensing Service

We implemented a prototype system to verify the practical feasibility of the proposed service. In this implementation, we configured the Mind Sensing Service (see Section 2.4), so that the LINE agent sends three questions twice a day (in the morning and the evening). Figure 2 shows a screen where we applied this configuration to the Mind Sensing Service.

In Figure 2, Miura_Morning0, 1, 2, 3 and Miura_Evening0-3 (the prefix Miura_ is omitted hereafter) represent 8 actions. For each action, we can see that target people, a message body, LINE as

Action 追加 削除 更新

ID	targets	message body	service
Miura_Evening0	daniki,shota-n,sinan,cmiura,yasuda,masa-n,chu_nakamu	%USER%さん, こんにちは。今日も一日お疲れ様でした！今から私が3つ質問するので、それぞれについて番号で答えてくださいね。	LINE
Miura_Morning0	daniki,shota-n,sinan,cmiura,yasuda,masa-n,chu_nakamu	%USER%さん, おはようございます！昨晩はよく眠れましたか？今から私が3つ質問するので、それぞれについて番号で答えてくださいね。	LINE
Miura_Morning3	daniki,shota-n,sinan,cmiura,yasuda,masa-n,chu_nakamu	【質問番号15】じっとしていることができないほど、落ち着かないと思いますか？【答え方】0（全く思わない）1（あまり思わない）2（やや思う）3（とても思う）※質問番号をつけて、当てはまる番号を返信してください	LINE
Miura_Evening2	daniki,shota-n,sinan,cmiura,yasuda,masa-n,chu_nakamu	【質問番号11】最近、あまり食欲がないと思いますか？【答え方】0（全く思わない）1（あまり思わない）2（やや思う）3（とても思う）※質問番号をつけて、当てはまる番号を返信してください	LINE
Miura_Evening1	daniki,shota-n,sinan,cmiura,yasuda,masa-n,chu_nakamu	【質問番号10】毎日が退屈だと感じることが多いと思いますか？【答え方】0（全く思わない）1（あまり思わない）2（やや思う）3（とても思う）※質問番号をつけて、当てはまる番号を返信してください	LINE
Miura_Morning1	daniki,shota-n,sinan,cmiura,yasuda,masa-n,chu_nakamu	【質問番号13】大抵は機嫌よく過ごすごことが多いと思いますか？【答え方】0（全く思わない）1（あまり思わない）2（やや思う）3（とても思う）※質問番号をつけて、当てはまる番号を返信してください	LINE
Miura_Morning2	daniki,shota-n,sinan,cmiura,yasuda,masa-n,chu_nakamu	【質問番号14】最近、食べ過ぎたりしていると思いますか？【答え方】0（全く思わない）1（あまり思わない）2（やや思う）3（とても思う）※質問番号をつけて、当てはまる番号を返信してください	LINE
Miura_Evening3	daniki,shota-n,sinan,cmiura,yasuda,masa-n,chu_nakamu	【質問番号12】くつろぐことが難しいと思いますか？【答え方】0（全く思わない）1（あまり思わない）2（やや思う）3（とても思う）※質問番号をつけて、当てはまる番号を返信してください	LINE

Time-based rule 追加 削除

ID	actions	since	until	interval(min)
Miura_MorningRule	Miura_Morning0,Miura_Morning1,Miura_Morning2,Miura_Morning3	06:30:00	08:00:00	1440
Miura_EveningRule	Miura_Evening0,Miura_Evening1,Miura_Evening2,Miura_Evening3	21:30:00	23:00:00	1440

Figure 2: Mind Sensing Service Console

a message delivery service. Morning0 (or Evening0) are greeting messages to start an inquiry in the morning (or evening, respectively). In Morning1, 2, 3 (or Evening1, 2, 3), we define concrete three questions asked in the morning (or evening, respectively) inquiry.

MorningRule and EveningRule represent time-based rules that execute the inquiries in the morning and evening, respectively. MorningRule executes four actions Morning0, 1, 2, 3 at 6:30, whereas EveningRule executes Evening0, 1, 2, 3 at 21:30. In both rules, the interval is set to 1440 minutes, so that MorningRule and EveningRule are executed exactly once a day. Thus, each target user receives three questions following a greeting message every morning at 6:30, as well as every evening at 21:30.

As mentioned in Section 3.3, the contents of the questions should be changed every day, preferably. However, we have not yet implemented a feature that automatically updates actions of the Mind Sensing Service. Therefore, in this prototype, we manually updated the message body of Morning1, 2, 3 and Evening1, 2, 3 every day.

4.2 Creating Questions

In order to create concrete questions in the inquiry, we extensively used the existing questionnaire sheets for mental illness. Specifically, based on GDS-15, PHQ-9, GAD-7, and GHQ60 described in Section 2.3, we created 42 questions in total. The primary goal of the proposed service is sustainable mind monitoring, but not rigorous screening tests of specific mental illnesses. Therefore, we intentionally excluded too strong questions such as those asking

death or suicide. We also unified the end of sentences of all questions, so that the elderly people could answer them easily.

We classified the 42 questions into three categories defined in Section 3.3. As a result, 13 questions were classified into Physicality, 21 were into Mentality, and 8 were into Sociality, as shown in Figure 3 (a) (b) (c), respectively. In the figure, sentences in bold face represent questions where the answer “Yes, I really think so” is assessed as most healthy. Other sentences represent questions where “Yes, I really think so” means the worst healthy.

Each subject was asked to answer three questions in the morning, and other three in the evening. Since six questions were consumed every day, the total 42 were covered in one week.

4.3 Analysis and Feedback

In the prototype system, the proposed service aggregates obtained scores within every week, and analyzes statistics. The service then identifies questions to which a user marked negative scores. Finally, as the feedback to the user, the service sends a further question that makes the user *reflect* himself with respect to the negative questions.

For this purpose, we extracted a *symptom* inferred by each question. The results are shown in the column “inferred symptom” in Figure 3 (a) (b) (c). In the feedback, the service shows the user the symptoms inferred from questions that have been negatively assessed in the past week. Showing concrete symptoms would promote the user to conduct self-reflection and externalize thought and anxiety as words.

iiWAS2019, December 2–4, 2019, Munich, Germany

Chisaki Miura¹, Haruhisa Maeda¹, Sachio Saiki¹, Masahide Nakamura^{1,3}, Kiyoshi Yasuda²

Questions (Physicality)	inferred symptom
Do you think you have trouble falling asleep or awake in the middle of night?	sleep disorder
Do you think you sleep too much recently?	sleep disorder
Do you think you feel tired and do not want to do anything?	fatigue and inertia
Do you think you have not had much appetite recently?	anorexia
Do you think you have eaten too much recently?	overeating
Do you think it is difficult to focus on reading newspapers or watching TV?	difficulty of concentration
Do you think you feel good and healthy?	unhealthiness
Do you think you want to take a fatigue recovery agent?	fatigue
Do you think you feel tired?	fatigue
Do you think you have a lot of headaches recently?	headache
Do you think you often feel like your head is heavy?	headache
Do you think you feel flushed or a chill?	heat or chill
Do you think you wake up in the middle of the night?	sleep disorder

(a) Physicality

Questions (Sociality)	inferred symptom
Do you think you feel satisfied with your daily life?	dissatisfaction with life
Do you think life is empty?	emptiness of life
Do you think you often feel bored every day?	boring life
Do you think you are happy?	unhappiness
Do you think you often feel that you are powerless?	powerlessness
Do you think you are full of energy?	inactivity
Do you think that the speed of movement and speaking has become so slow that others notice it?	mental disorder
Do you think you cannot calm down as much as others notice?	mental disorder

(c) Sociality

Questions (Mentality)	inferred symptom
Do you think your daily activities and interests have declined?	decline of activity and interests
Do you think you are often driven by vague anxiety in the future?	future anxiety
Do you think you want to stay home rather than going out or doing new things?	decline of activity
Do you think you are more worried about forgetting things than anything else?	concern over forgetfulness
Do you think you feel that there is no hope?	despair
Do you think you have little interest or enjoyment of things?	decline of interests
Do you think you feel depressed and hopeless?	despair
Do you think you feel nervous or anxious recently?	tension, anxiety, oversensitive
Do you think you have been too worried recently?	worry
Do you think it is difficult to relax?	difficulty of relaxing
Do you think you feel restless?	restlessness
Do you think you feel annoyed and angry recently?	anger
Do you think you might be afraid that something terrible will happen?	fear
Do you think you cannot sleep because of worries?	worry
Do you think you always feel stress?	chronic stress
Do you think you might get frustrated and angry?	anger
Do you think you are scared of something for no particular reason?	fear
Do you think everything is more burdensome for you than usual?	stress
Do you think you feel anxiety or tension?	anxiety, tension
Do you think you often seem to be in a good mood?	bad mood
Do you think you cannot stop worrying?	worry

(b) Mentality

Figure 3: Created Questions

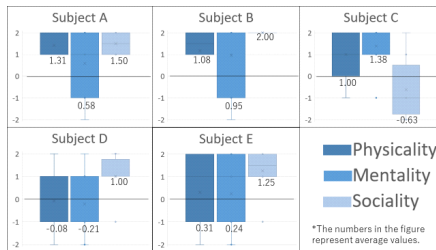


Figure 4: Box Plots Visualizing the Scores

5 EXPERIMENTAL EVALUATION

5.1 Overview

We have performed a preliminary experiment using the prototype implementation. The experiment was conducted with six subjects for seven days from July 2nd to 20th, 2019. The subjects were two men in the 70's, a man in the 40's, and three men in 20's. The proposed service was originally intended for the elderly generation. However, we also recruited young subjects in the experiment in order to evaluate practical feasibility of the service.

The experiment has been approved by the Research Ethics Committee of Kobe University Graduate School of System Informatics (No. R01-02).

5.2 Experimental Results

First, we describe the results related to the practical feasibility. During the seven-day experiment, five of the six subjects (let the five be A, B, C, D, and E) were able to respond to the inquiries, successfully. However, the one in the 70's (let the one be F) gave almost no response. After the experiment, we asked subject F the reason why he did not answer the questions. He told us that he did not notice the question messages due to the narrow screen setting of the LINE application. We should have checked the screen setting before the experiment. Furthermore, we found that the responses from the subjects were not always on time. We assumed that subjects should answer three questions in the morning, and other three in the evening. However, there were some cases where six questions were answered at once. We also found that some answers were missing. Some subjects complained that it was balky to input the answers of the three questions by text typing.

Next, we see the result of the mind monitoring achieved by the proposed service. Figure 4 shows box plots visualizing the scores of the five subjects. Each box plot represents the distribution of scores for three categories for a subject. By focusing on average values of each category, we can observe characteristics on individual's mental states. For example, the average values of subject D are -0.08, -0.21, 1.00 for Physicality, Mentality, and Sociality, respectively. We can see that his mental states were a bit inadequate in physical and mental aspects, and that states in social aspect was maintained. The height of each box indicates the degree of variance in the answers. Considering four subjects except subject C,

we can see that Mentality was the most variable, and Sociality was less variable.

Based on the results, feedback was created using the method described in Section 4.3, and sent to each subject. The following shows an example of feedback sent to subject B.

Good morning, Mr. B! According to your answers during 7/2-7/8, it seems that you were recently feeling

- decline of activity and interests
- fatigue and inertia
- difficulty of relaxing
- anxiety
- decline of concentration
- concern over forgetfulness
- chronic stress

Do you have any thoughts in mind? If you have any concern or anxiety, please feel free to talk to me.

Then, subject B responded to this feedback as follows.

Thank you. Recently, I have been very busy with my work, and I had no time to relax. I tend to forget various things because there are too many tasks to do. I believe that is why I am feeling chronic stress. However, the work is going well, and everyone is doing his or her best, so I think that this kind of anxiety will disappear soon.

It is clearly seen that subject B looked back on himself, and externalized his mind owing to the feedback. In other words, the feedback promoted his self-reflection. From this fact, we can confirm the effectiveness of the feedback to a certain extent. After the experiment, we interviewed the subjects what they felt about the service. We obtained various comments from the subjects. They are, for example, “In feedback, there were some items that did not apply to my situation”, “I found that my psychological condition was dangerous, as too many things were pointed out.”.

5.3 Discussion

The preliminary experiment with the prototype went mostly very well. On the other hand, from the results and the subsequent interview, we found that the prototype still has two limitations.

Firstly, there is an issue of *immediate response*, which means that the answer to the inquiry can be delayed or forgotten. LINE is an excellent chat communication tool, but there is no mechanism to guarantee the response. The fact that the subjects had to use the text input for answering questions was also affecting the responsiveness. We need to devise methods for easy response and motivation supports.

Secondly, the effectiveness and satisfaction of feedback were also inadequate. The proposed feedback method pointed out *all* symptoms inferred from questions that have been evaluated negatively even once. However, considering the comments such as “there were items that did not apply to me” or “there were too many items pointed out”, this method may be generating hypersensitive and pessimistic feedback. Further improvement in generating the feedback will be necessary.

6 CONCLUSION

In this paper, we have proposed *Mind Monitoring Service* that monitors internal minds of elderly people to support sustainable in-home long-term care. Using our technique of Mind Sensing, an agent asks the user questions to acquire the mental state. The service assesses the mental state from viewpoints of Physicality, Mentality, and Sociality, by scoring the answers. The service finally sends the feedback showing symptoms inferred from questions with negative scores. We also implemented a prototype of the proposed service and conducted a preliminary experiment. The experimental results show that data characterizing mental states of individual subjects was obtained successfully, and that some subjects externalized their minds by feedback from the service.

In our future work, we conduct more extensive experiments with many elderly people. For this purpose, we plan to improve the human-agent interaction and the feedback method. It is also a challenging but important issue to present appropriate self-support methods for individual mental states.

ACKNOWLEDGMENTS

This research was partially supported by JSPS KAKENHI Grant Numbers JP19H01138, JP17H00731, JP18H03242, JP18H03342, JP19K02973.

REFERENCES

- [1] LINE Corporation. [n.d.]. LINE. <https://line.me/en/>.
- [2] David P. Goldberg, Yasuaki Nakagawa, and Ikuo Daibo. 1985. *The General Health Questionnaire*. Nihon Bunka Kagakusha.
- [3] Government of Japan. 2019. Annual Report on the Aging Society (2019). <http://www.cao.go.jp/>.
- [4] Haruhisa Maeda, Sachio Saiki, Masahide Nakamura, and Kiyoshi Yasuda. 2019. Memory Aid Service Using Mind Sensing and Daily Retrospective by Virtual Agent. In *10th International Conference, DHM 2019, Held as Part of the 21st HCI International Conference, HCII 2019*, Vol. LNCS 11582. 353–364. Orlando, USA.
- [5] Haruhisa Maeda, Sachio Saiki, Masahide Nakamura, and Kiyoshi Yasuda. 2019 (to appear). Rule-Based Talking Service to Elderly at Home for Efficient Mind Sensing. In *IEICE Technical Report*.
- [6] Kumiko Muramatsu. 2014. An up-to-date letter in the Japanese version of PHQ, PHQ-9, PHQ-15. <https://ci.nii.ac.jp/naid/120005482683/>. , 35–39 pages.
- [7] Masahide Nakamura, Kenji Hatano, Jun Miyazaki, Kiyoshi Yasuda, Noriaki Kuwahara, Hiroaki Kazui, Sachio Saiki, Seiki Tokunaga, Mihoko Otake, Naoki Kodama, and Naoko Kosugi. 2019–2023. Developing a System for Self-care and Mutual-aids of Elderly People at Home Based on Externalization of Internal States. *JSPS KAKENHI, Grant-in-Aid for Scientific Research (A)* 19H01138 (2019–2023).
- [8] Shota Nakatani, Sachio Saiki, Masahide Nakamura, and Kiyoshi Yasuda. 2018. Generating Personalized Virtual Agent in Speech Dialogue System for People with Dementia. In *Digital Human Modeling 2018 (DHM 2018), Held as Part of HCI International 2018*, Vol. LNCS 10917. Springer, 326–337. Las Vegas, USA.
- [9] Morihiro Sugishita and Takashi Asada. 2009. Geriatric Depression Scale and minus; Short Version-Japanese, GDS-S-J. *Japanese Journal of Cognitive Neuroscience* 11, 1 (2009), 87–90. <https://doi.org/10.11253/ninchishinkeikagaku.11.87>
- [10] Masatoshi Takeda and Toshihisa Tanaka. 2007. *E de Miru Kokoro no Hoken-shitu (Mental clinic with pictures)*. Alta Publishing Co., Ltd.
- [11] The Ministry of Health, Labor and Welfare in Japan. 2009. Depression prevention and support manual (revised version). <https://www.mhlw.go.jp/topics/2009/05/dl/tp0501-1i.pdf>.
- [12] The Ministry of Health, Labor and Welfare in Japan. 2013. Community-based Integrated Care System. https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/hukushi_kaigo/kaigo_koureisha/.
- [13] World Health Organization. 1946. Constitution of the World Health Organization. <https://www.who.int/>.
- [14] A Young. 1982. The Anthropologies of Illness and Sickness. *Annual Review of Anthropology* 11 (1982), 257–285.