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Chatbots and robots: a framework for the self-management of occupational stress

Akihiro Yorita[1*], Simon Egerton[1], Carina Chan[2] and Naoyuki Kubota[3]

Abstract

We have developed a stress management framework aimed at helping healthcare professionals manage occupational stress. A chatbot is used to gather pertinent information from a user through regular conversation which is processed via a fuzzy inference model to derive their level of occupational Comprehensibility, Manageability, Meaningful and overall occupational Sense of Coherence (SOC). This analysis feeds into a Peer Support model which selects the best intervention aimed at enhancing a user's stress-coping abilities and reducing their levels of occupational stress. A trial has been conducted with working adults, and the results were examined using a questionnaire supported by Technology Acceptance Model, which showed that the chatbot could recognize the user's SOC, but left a challenge: few users wanted to continue using it in their daily lives.

Keywords Artificial intelligence, Peer support, Fuzzy inference, Sense of coherence, Chatbot

Background

One of the major causes of the global illness burden is mental health problems [1]. Stress that causes decreased motivation, emotional instability, and poor physical condition has a great impact on the maintenance of physical and mental health, and in the worst case, it may lead to crimes such as suicide and murder. It is widely known from much evidence, including experimental studies, clinical studies, and epidemiological studies, that stress is associated with the onset and course of illness. The World Health Organization (WHO) defines mental health as a "state of well-being in which the individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community" [2]. To maintain good mental health, you must be happy by recognizing, working, and contributing to your abilities. However, the global economy is estimated to lose $ 16 trillion between 2011 and 2030 due to labor and capital losses due to mental illness [3]. This is a prediction of poor mental health of people, but Common Mental disorders (CMD) to the working population, such as depression, anxiety, and adjustment disorders, are gaining more and more attention among researchers [4]. The prevalence of these disorders in the working population is high, affecting individuals around the world [5]. CMD can lead to reduced job performance and reduced participation in work, such as long-term illness [6]. As a result, CMD not only threatens the well-being of affected individuals, but also carries significant social and financial costs [7]. On average, people usually spend one-third of their lives working [8]. Therefore, the workplace is one of the key environments that can affect the quality of life and emotional and physical well-being. Therefore, improving workplace stress also leads to improving mental health.

Tools for stress management can now be done with smartwatches and activity trackers, but before they appeared, psychotherapy tools were used. With

*Correspondence:
Akihiro Yorita
A.Yorita@latrobe.edu.au
[1] Department of Computer Science and Information Technology, La Trobe University, Melbourne, Australia
[2] Department of Psychology, Counselling and Therapy, La Trobe University, Melbourne, Australia
[3] Graduate School of System Design, Tokyo Metropolitan University, Tokyo, Japan

increasing access to mobile internet and smartphones, smartphone-based mental health (mHealth) apps represent a unique opportunity to increase the availability and quality of mental health self-care. In 2015 alone, a survey of the 15,000 mHealth apps conducted by the World Health Organization (WHO) found that 29% of them focused on diagnosing, treating, or supporting mental health [9].

In our study, we developed a stress management framework that incorporates chatbots and robots to talk to, learn, and personalize peers with individual stressor profiles to help manage individual occupational stress. Moonshot Goal 3: "Realization of AI roots that autonomously learn, adapt to their environment, evolve in intelligence and act alongside human beings, by 2050." and the R&D project on "Adaptable AI-enabled robots to create a vibrant society" aim to realize a robot society in which all people can live healthy lives [10]. We believe our framework will help support the project.

Related works

Most mental health chatbots target depression and anxiety; others include autism, suicidal ideation, substance abuse, post-traumatic stress disorder, dementia, self-compassion, mindfulness, and others. A representative list of these chatbots is shown in Table 1.

Woebot is the number one downloaded chatbot and provides emotion-focused support using Cognitive-Behavioral Therapy (CBT) [11]. Its use is to improve depression by teaching about CBT. In an experiment, a comparison was made between the chatbot and texting, showing that the chatbot's assistance was more effective. The application has also been extended to drug abuse prevention. Chatbots that provide similar assistance include Wysa; Wysa is an AI-driven pocket penguin that also performs chat interactions based on CBT skills [12]. Help4mood also conducts CBT and is targeted at users who are depressed, but its use is screening [13]. Aquabot diagnoses symptoms for autism [14]. Shim is a mental health chatbot designed for non-clinical samples [15]. In a controlled trial, users of the Shim experienced increased well-being and reduced perceived stress. Charlie can memorize appointments and medicines, connect remotely with doctors and family members, and entertain and support the elderly [16]. Charlie is designed as an empathetic, sensitive, sociable, and approachable child robot that accompanies the elderly through innovative strategies that can be applied to preventive mental health care, such as gamification, active notification, and promotion of self-compassion and considers solutions to improve their quality of life. Gamification techniques allow Charlie to monitor whether a user has followed Charlie's suggestions, and if so, it gives the user a "bot-coin" (a kind of reward). This approach aims to enable users to lead healthy lives in exchange for rewards. Vincent is a chatbot that uses helper therapy, and the scenario is designed to receive support from users and is mentally strengthened by self-compassion [17]. In the experiment, they compared the case where the chatbot assists the user and the case where the user assists the chatbot, showing that the latter enhances the user's self-compassion.

Although there are many chatbots that use CBT, CBT is taught as content, but it is not possible to perform therapies that human counselors do. This is a very difficult part, but the bottleneck is that chatbots recognize human automatic thinking and schemas and correct cognitive distortions. Charlie's bot coin is a good mechanism. It seems that there are a certain number of people who do not trust bots empirically, but it will be easier to support them if they can be made to obey bots by giving them rewards. Vincent showed that chatbots receiving support from the user increases the user's sense of self-compassion, but there is concern that if the user has to constantly support the chatbot, the user may gradually become tired. When the user is either receiving or giving support unilaterally, the two parties are not on equal footing, and the support usually does not last long. Therefore, it is necessary to have criteria to determine when to receive or give support.

Next, we discuss chatbots for stress management shown in Table 2. CBT can also be used for stress management and is widely used, but there are also chatbots that use Motivational Interviewing (MI). Bonobot was developed to address mental health concerns with the goal of designing conversational sequences that take into account both the technical and relational elements of MI [18]. A simple conversation sequence was

Table 1 Mental healthcare chatbot

	Woebot (2017)	Help4Mood (2016)	Aquabot (2017)	Shim (2017)	Charlie (2021)	Vincent (2019)
Type of support	CBT	CBT	–	Positive psychology	Gamification	Helper therapy
Helps with	Depression, Substance use	Depression	Autism	QOL	Elderly care	Mental health strengthen
Used for	Content delivery	Screening	Diagnosis	Content delivery	Content delivery	Content delivery

Table 2 Stress management chatbot

	Bonobot (2019)	Stress detox (2021)	Popbots (2021)	Atena (2021)
Type of support	Motivational interview	CBT Mindfulness	CBT Positive psychology	
Accomplishment	Encourage a chance of self-reflection	Reduction in stress, significant increase in subjective well-being	Decrease in depression symptoms	Higher engagement and lower attrition rates
Helps with	Graduate students	University students	Over 18 years old	University students
Used for	Web application	Facebook messenger	Telegram	

designed using different combinations of MI skills to follow the four processes of MI. Feedback from 30 graduate students suggests that question ordering and MI-compliant statements may facilitate conversations for stress management and facilitate introspection opportunities. Stress detox chatbots deliver content such as CBT on Facebook Messenger [19]. Twenty-one sessions were delivered daily, each session lasting 5–7 min. Of the 21 days, the first week focuses on the physiological sensations associated with stress and anxiety, the second week focuses on the cognitive assessment of stress and anxiety, and the third week is the behavioral response. The chatbots are designed on a rule basis. On average, participants completed the 11-day program. Experimental results showed that chatbots reduced stress and significantly increased subjective well-being, although there was no change in anxiety symptoms. A fully automated, shallow chatbot mobile suite (called a Popbot) could act as a new breed of chatbot and further complement human support in the stress management support ecosystem [20]. Participants with multiple chatbots were found to be more likely to agree that interventions help reduce stress compared to participants in control with a single chatbot. It has been shown that half of the typical daily stressors can be discussed with chatbots, potentially reducing the burden of human coping resources. Atena, a psychoeducational chatbot that supports healthy coping with stress and anxiety, has the potential to achieve the scalability of healthy coping interventions by reducing the cost of digital mental health interventions and supporting prevention [21]. The user was asked to use Atena for 4 weeks. This provided a healthy coping strategy based on cognitive behavioral therapy, positive psychology, and mindfulness techniques.

Both mental health care chatbots and stress management chatbots are basically providing support based on CBT, but they cannot provide counseling like a human therapist and can only provide referrals to CBT. Hence, they are not able to provide support. In addition, when CBT is used, the chatbot's role is limited to that of a therapist, making it unsuitable for long-term use. To address this problem, we propose the use of peer support as a support method and the use of SOC for stress recognition. Conventionally, chatbots have tried to replace therapists, but in peer support, the chatbot becomes not only the therapist but also the patient. In this way, the chatbot can have the role of being supported as well as supporting and may establish a long-term relationship with the user. The role can also be determined by the SOC to determine whether the user should receive or provide support.

In essence, our framework personifies a stress management buddy that can be present across platforms, including multiple robots physically located at home, in the office, and smart devices, phones for example, running chatbots when individuals travel between locations. Our framework comprises three core models, a conversation model for acquiring state information about the individual and measuring their stress level, a Sense of Coherence (SOC) model for evaluating the individuals' state of stress, and a Peer Support model, which uses the SOC to select a suitable peer support type and action it. In order to match the contents of the conversation with the characteristics of the user, reinforcement learning is combined with fuzzy control to estimate the state of the user based on Sense of Coherence. We show selecting appropriate conversation content and support depending on the user's ability to deal with stress.

Method: stress management framework

System architecture

Our stress management buddies persona is implemented across two robot platforms and a chatbot (Fig. 1). We use an NAO robot within the home, a Double 2 robot within the workplace, and a chatbot everywhere in between. This blended approach, where a buddy persona is present across different platforms, has been trialed with the ITACO system project, which blends robots and virtual agents into a seamless platform for human–robot interaction with continuity across locations [22]. The results

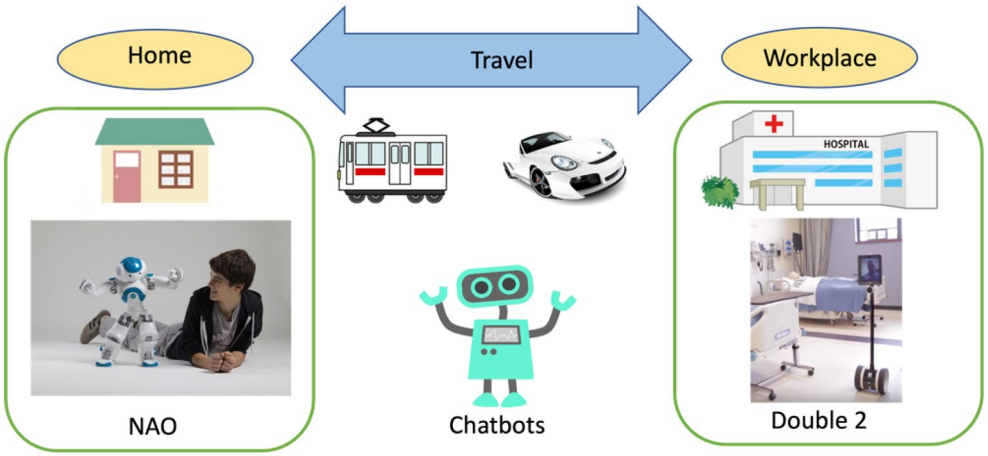


Fig. 1 System configuration

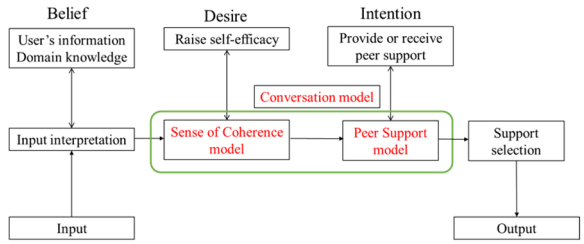


Fig. 2 BDI architecture within our stress management framework

of the ITACO team showed that users treat the robot and the virtual agent as the same entity.

Software architecture

We use a Belief-Desire-Intention (BDI) architecture to represent the internal state of our buddy persona within our framework [23] (Fig. 2). Speech and text are used as inputs from the user, these inputs are then interpreted by the system to derive beliefs about the users' state. The buddy persona also has knowledge about occupational stress management.

The desire of our framework is to improve an individual's self-efficacy [24] in stress management. Self-efficacy is a concept proposed by Bandura, expressed across three dimensions: Level, Strength, and Generality. It measures an individual's sense of task performance and whether they can do a task. For example, it was used to evaluate stress management competence in stress management training [25], but it is not suitable for finding stressors because it deals with only the tasks. A concept close to the idea of self-efficacy, related to the task of stress management, is the Sense of Coherence (SOC) model [26]. The SOC model consists of three measures: Comprehensibility (Co), Manageability (Ma), and Meaningfulness (Me). Comprehensibility means that people can understand their situation and predict their near future. Manageability is the sense that people can manage their situations. Meaningfulness means people can understand the meaning of their life. SOC Manageability is similar to self-efficacy, with the additional two measures of Comprehensibility and Meaningfulness. SOC offers a richer evaluation of occupational stress than self-efficacy and is the measure we adopt in our framework. Within our framework, we measure SOC against the task of managing occupational stress to confirm whether self-efficacy increases. We measure our desire to enhance self-efficacy i.e. the user has a high SOC value.

The intention of our framework is to provide (or receive) peer support. Peer support models improve self-efficacy [27], fulfilling our framework's overall goal. The definition of peer support is "social emotional support, frequently coupled with instrumental support that is mutually offered or provided by persons having a mental health condition to others sharing a similar mental health condition to bring about a desired social or personal change" [28]. In order to achieve this, emotional and informational support are used [29]. We use the helper therapy principle to build a sense of companionship between the framework's buddy persona and the individual [30]. After the intention model has selected a support action, the framework either carries out a peer support action or receives a peer support action from the individual. This bidirectional peer support model follows helper therapy principles for building companionship and improving self-efficacy levels.

Chatbot

We used a chatbot for smartphones, considering the ease of conducting experiments because many chatbots

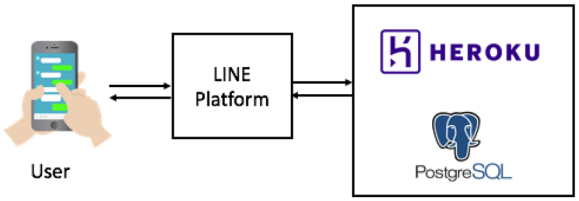
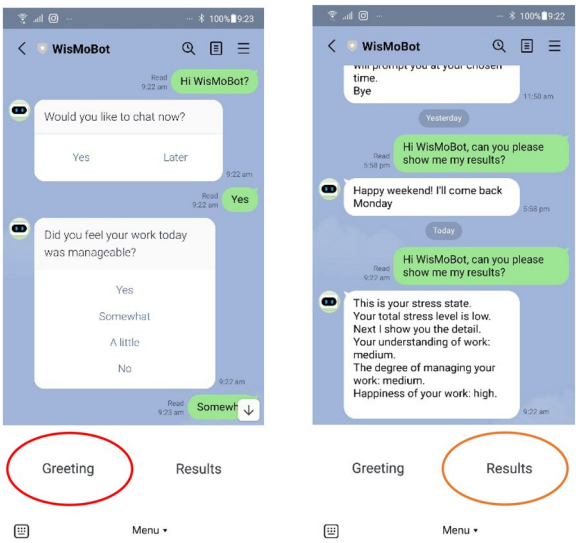


Fig. 3 Chatbot system configuration



(a) (b)

Fig. 4 Chatbot screen for communication

are developed for smartphones. To develop the chatbots, we used the LINE chatbot platform. LINE is a free social networking service (SNS) application that provides an API for creating chatbots. The LINE Messaging API is an application programming interface that enables user interaction and conveys user input to the LINE application server [31]. The system configuration is shown in Fig. 3.

The user communicates with the chatbot by entering free text or by selecting a fixed response option from a menu presented by the chatbot. The chatbot then processes the user's input and responds according to a set of logic. Information about the user's stress state and the chatbot's conversational state is stored in PostgreSQL.

The screen for communicating with a chatbot is shown in Fig. 4. On the normal screen, the user has two buttons. The button on the left (Fig. 4a) is the greeting button, which calls the chatbot. Basically, the chatbot sends a message at a specified time to start a conversation, but this button is used when the user wants to speak to the chatbot. The Result button (Fig. 4b) is used to check the assessment of stress coping ability made by the chatbot.

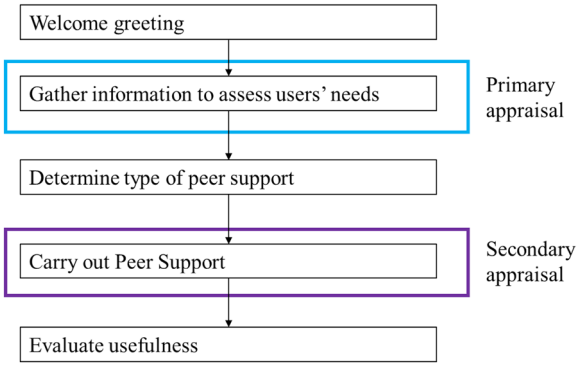


Fig. 5 5-phase conversation model

Table 3 Questionnaires

SOC	Non SOC
SOC scale [26]	Perceived stress scale [41]
Work SOC scale [34]	Ryff's psychological well-being scales [42]
	Hassles scale [43]

When a user wants to check his or her stress status, the chatbot will tell him or her when the button is pressed.

Framework models

Conversation model

We developed our conversational model for stress management (Fig. 5) based on the 5-phase conversational scheme of van der Zwaan [32]. Under this scheme, stress and coping are evaluated with reference to Cognitive Appraisal Theory by Lazarus and Folkman [33]. Phase 1 consists of a simple conversation, starting with a greeting and following on with a dictionary of prepared sentences to engage the individual. Phase 2 of the conversation model is where we measure SOC based on individual responses. Thereafter, the SOC informs the Peer Support model, which decides the type of peer support for actions in Phase 3. If the individual consents to the peer selection action, the framework, via its robot or chatbot persona, will provide support in Phase 4. In Phase 5, the user evaluates the efficacy of the provided support.

We created a dictionary of sentences for the conversation in Phase 2 by extracting questions from several relevant SOC-related questionnaires. The questionnaires used are shown in Table 3.

We have two policies to develop questions. For one thing, SOC has been scaled to suit the measurement of occupational stress, the Work-SOC scale [34]. We correspond each SOC measure with the Job-Demand-Control-Support model [35] as shown in Fig. 6. Lower SOC values on the scale represent high stress, higher

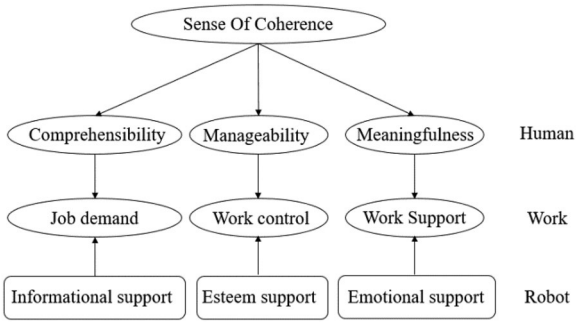


Fig. 6 Sense of Coherence and Job-Demand-Control-Support model

Table 4 Type of GRRs

Type	Resources	Purpose
Physical, biochemical	Genetics, immune system	–
Artifactual-material	Money, residence, diet, clothes, power, position, service, etc	Co
Cognitive, emotional	Knowledge, personality	Ma, Me
Valuative-attitudinal	Flexibility, rationality, forecast	Ma
Interpersonal-relational	Social networking services	Me
Macrosociocultural	Religion, philosophy	–

Table 5 SOC questions

Dimension	Question examples
Comprehensibility	Do you think your work is structured?
Manageability	Do you feel your work is easy to influence?
Meaningfulness	Do you feel your work is meaningful?

values represent lower stress. We can use the scale as the basis to develop questions for conversations with the user.

The other is Generalized Resistance Resources (GRRs) as criteria for classifying the questions of non-SOC questionnaires to associate them with SOC. The SOC model defines a set of GRRs (Table 4) that define coping mechanisms that a person generally has available to them to help them manage their stress. A person's success in coping with their stressors depends on the strength of their SOC measures and the amount and makeup of their GRRs. Our peer support intention aims to stimulate the GRRs to reduce stress levels. We map the non-SOC questions to GRRs as such, Artifactual-Material GRR maps to Comprehensibility, Valuative-Attitudinal GRR and Cognitive GRR maps to Manageability, and Emotional/Interpersonal-Relational GRR corresponds to Meaningfulness. For example, Artifactual-Material shows that having more money makes it possible to cope with stressors.

Table 6 Type of user replies

Grade	Reply examples
Big	Always, frequently, great, often, yes
Medium	Fairly, good, kind of, somewhat, sometimes, so-so
Small	A bit, a little, barely, hardly, rarely, seldom
Zero	Bad, never, no, nothing, poor, rough

The questions extracted from the validated SOC questionnaires (as listed Table 3), were extracted and categorised as addressing one of the three SOC measures, comprehensibility, manageability, and meaningfulness (Table 5).

Sense of coherence and peer support models

In order to provide each support by a robot, SOC evaluates the user's state and decides whether to provide or receive support. We use fuzzy inference [36] to express SOC. We calculate membership values of each dimension of SOC by the following equation, where i means the label of fuzzy sets. We use Small, Medium, and Big. j means the dimension of SOC: Co, Ma, Me. They have two roles in the framework. One is to calculate the total value of SOC. The second is to know the weakest part of the user if the total value of SOC is below the threshold.

Each dimension's value is calculated using the average value of a user's reply to the questions (Table 4), and then the membership value is calculated as follows.

$$\mu_{A_{i,j}} = \exp\left(-\frac{(a_i - x_j)^2}{b^2}\right) \tag{1}$$

where ai and b are the central value and the width of the membership function Ai,j; When the label is small, $a=0$, when the label is medium, $a=0.5$, when the label is big, $a=1$, and $b=0.25$. x is the input value of each dimension of SOC and depends on the user's replies. An example of the reply is shown in Table 6. When the grade is big, $x=1$, the grade is medium, $x=0.5$, the grade is small, $x=0.25$, the grade is zero, $x=0$.

After membership values are calculated, then a fitness value is calculated.

$$\mu_i = \prod_{j=1}^{m} \mu_{A_{i,j}}(x_j) \tag{2}$$

where m is 3. The outputs of the fuzzy system are used for deciding the total value of sense of coherence, SOCtotal,

$$SOC_{total} = \frac{\sum_{i=1}^{n} \mu_i w_i}{\sum_{i=1}^{n} \mu_i} \tag{3}$$

Table 7 Fuzzy rule base

Manageability	Small	Medium	Big
Co			
Meaningfulness is small			
Small	Small	Small	Small
Medium	Small	Small	Medium
Big	Small	Medium	Big
Meaningfulness is medium			
Small	Small	Small	Medium
Medium	Small	Medium	Big
Big	Medium	Big	Big
Meaningfulness is big			
Small	Small	Medium	Big
Medium	Medium	Big	Big
Big	Big	Big	Big

where the value of w is 0.25 for Small, 0.5 for Medium, 0.75 for Big. n is 27. IF–THEN rules are shown in Table 7. The vertical axis is Comprehensibility, the horizontal axis is Manageability, and the upper figure is when Meaningfulness is Small, the center figure is when Medium and the lower figure is when Big. The singleton of the ith rule is decided.

If SOC_{total} is smaller than the threshold, the support would be selected by the lowest value of each dimension to support the weakest part of the user. Otherwise, according to the Helper therapy principle, the robot asks the user for support.

About the threshold value of SOC_{total}, T is changed by the reward, which is given in phase 3 as the following equation. When helper therapy is selected, the reward is multiplied by minus 1. By this, it is possible to reflect on the user's preference.

$$T \leftarrow (1-\beta)T + \beta R \tag{4}$$

$$R = \begin{cases} 1 \\ 0.5 \\ -0.5 \\ -1 \end{cases} \tag{5}$$

Here the initial value of T is 0.5 and β is 0.1. The reward is also decided by the reply and when the grade is Big, R is 1, when Medium, R is 0.5, when Small, R is -0.5, and when Zero, R is -1.

Support selection patterns are designed to support information when comprehensibility is low, esteem support if manageability is low, and emotion support when meaningfulness is low (Fig. 7). When the SOC_{total} is low and there are same values in the element of SOC, priority is given in order of meaningfulness, manageability, comprehensibility.

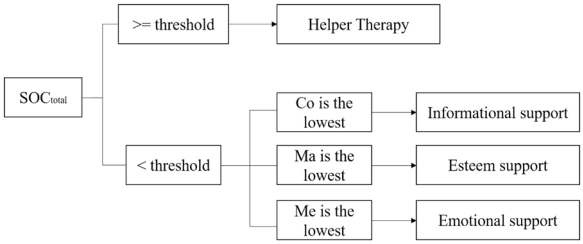


Fig. 7 How to decide the support

Also, to provide appropriate support for users, reinforcement learning is used as a question selection method to choose practical questions which derive essential information from the user [37]. In this research, reinforcement learning is used to suggest appropriate support for stress management. The flowchart of reinforcement learning in conversation is depicted in Fig. 8.

ε-greedy selection chooses an action at random by a certain probability epsilon, and the rest chooses the action with the greatest Q-value. By ε-greedy selection, the robot chooses the contents of the conversation. Then the user replies to the question. According to the contents of the reply, the robot evaluates it by fuzzy inference and updates the element value of SOC which is the same dimension as the question.

If all elements of SOC are set, and some conversations are made, the robot proposes support depending on the total value of SOC calculated by fuzzy inference. Then the user replies and evaluates the support as a reward.

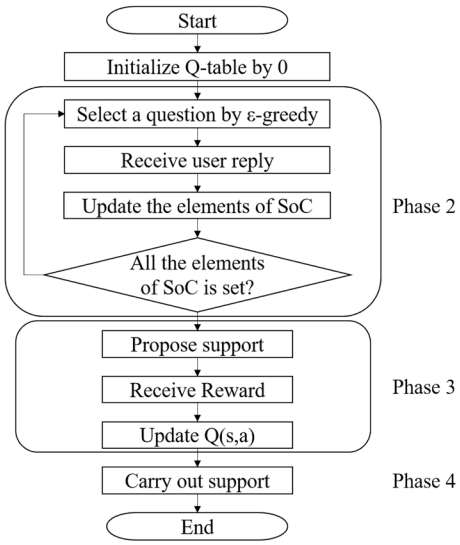


Fig. 8 Flowchart of reinforcement learning in conversation

After receiving a reward, the robot updates Q-value, which the questions were selected, and carries out social support or receives support from the user.

Q-table is updated by the following equation.

$$Q(s,a) \leftarrow (1-\alpha)Q(s,a) + \alpha\left(R + \gamma \max_{a\prime} Q(s\prime, a\prime)\right) \tag{6}$$

where, the number of state (s) is 3. Here the state means which dimensions the chatbot is about to ask for the user. The states are selected based on the lowest value of the element of SOC. The number of action (a) in each dimension is 15, i.e. total number of questions is 45, α is 0.5, and γ is 0.9. ε is 0.1. R is the same as Eq. (5).

Experiment results

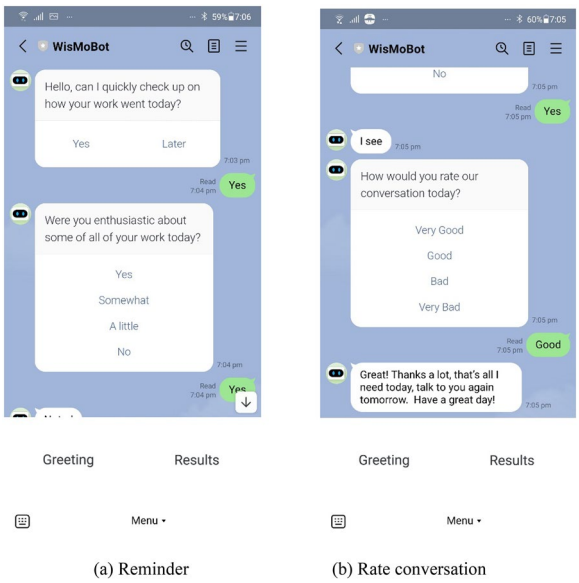
Scenario/subject

The purpose of the experiment is to investigate the usefulness of the system developed in this study. In particular, we will confirm whether SOC can measure the stress state of users with a chatbot-based system, and obtain feedback from users for future development.

Participants were recruited using Facebook and the university's mailing list and were restricted to adults over 18. There were 15 registrants. Participants should talk to the chatbot once a day, so it is desirable to have five conversations during the experiment. 12 people completed the experiment, 2 males and 10 females.

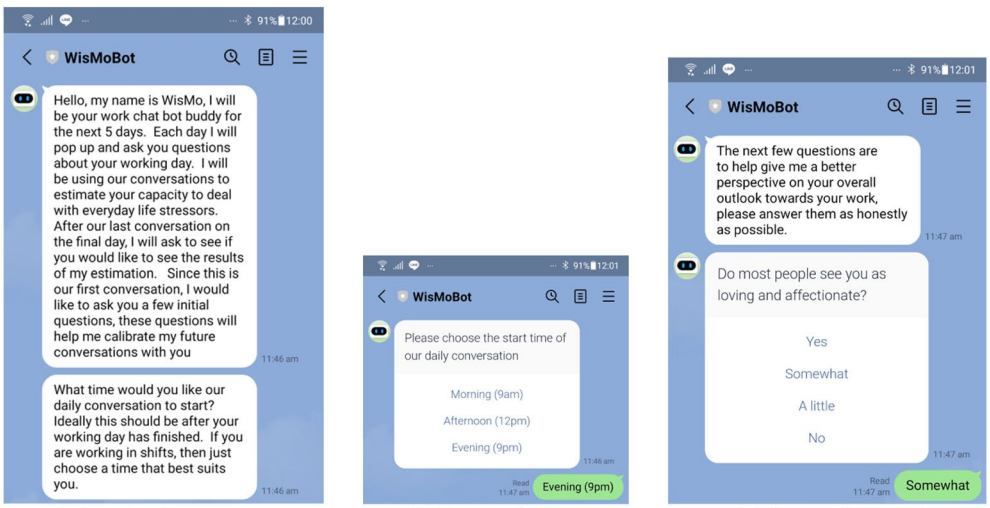
On the first day of the experiment, we first ask participants to install the LINE app and add the WisMoBot account as a friend from the QR code. Adding WisMoBot as a friend will send the user a message for guidance (Fig. 9a). Next, select what time the user would like WisMoBot to send them a message to encourage them to interact with WisMoBot daily (Fig. 9b). Here we generally recommend choosing the time after work. Afterwards, end the interaction after answering 15 SOC questions to test the initial state of the user's ability to cope with stress (Fig. 9c).

From the 2nd to the 4th day, they will receive a message from the WisMoBot at the set time, answer simple questions and perform a stress check (Fig. 10a). Users can set the chatbot to send messages at the end of the working day so that they can reflect on their work. This is important to avoid work fatigue dragging on to the next. It asks



(a) Reminder (b) Rate conversation

Fig. 10 Chatbot screen of 2nd to 4th day

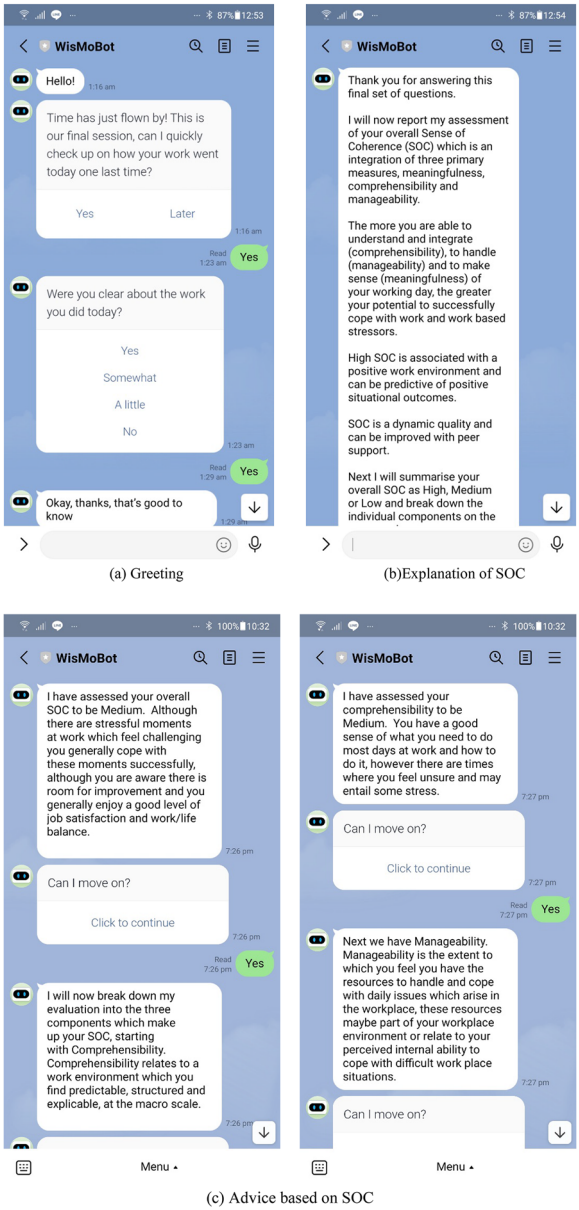


(a) Introduction (b) Set a reminder (c) Answer the questions

Fig. 9 Chatbot screen of the first day

the user questions retrieved from the stored question databank. Three questions are randomly selected for each dimension of the SOC, and the process ends when all questions are answered. The question data bank is shown in the Appendix. The answer menu presents the user with four answer choices: yes, somewhat, a little, and no. The user is then asked to rate the conversation with the chatbot by answering one of four fixed feedback options: "Very good", "Good", "Bad" or "Very bad" (Fig. 10b). This updates the likelihood of the question being chosen for the next conversation with WisMoBot. The likelihood of a question being chosen reflects the user's preference.

On the final day of the conversation (Fig. 11a) the users' SOC is calculated and the user is presented with a reminder of what SOC is (Fig. 11b) and a summary of WisMoBot SOC analysis broken down into the three SOC components Co, Me Ma (Fig. 11c).



(a) Greeting (b)Explanation of SOC

(c) Advice based on SOC

Fig. 11 Chatbot screen of the last day

Results section

The questionnaire of Table 8 was administered after the experiment.

Questions 1–3 and 11–15 were categorized by the usefulness of stress management by the SOC, and questions 4–10 were categorized by the usefulness of the chatbot for peer support analysis.

We used Technology Acceptance Model (TAM) as a reference for creating questions. TAM is a model of human behavior that uses information systems and is widely used as a model for analyzing the factors that lead people to accept information systems. The model identifies four factors that lead individuals to use information systems: "Perceived Usefulness," "Perceived Ease of Use," "Attitude toward using," and "Behavioral Intention to use" [38]. Perceived Usefulness is the subjective expectation that using the information system will improve one's performance. Perceived Ease of Use is the degree to which the user expects that using the information system requires no effort on his/her part. Attitude toward use is the individual's positive (negative) feelings about the desirability of using the information system. Behavioral Intention to Use" is the intensity of the user's will to use the information system. The responses to the questionnaire were rated on a 5-point scale from 1 to 5 because the participants answered it by their smartphone, although the original questionnaire is 7-point scale. For the analysis, the response groups were divided into three: respondents who gave a rating of 4 or 5 were in the Positive group, those who gave a rating of 3 were in the Neutral group, and those who gave a rating of 1 or 2 were in the Negative group.

- User Evaluation of Chatbots and SOC Evaluation (Table 9)

From Q1 and Q2, half of the respondents judged that chatbots are related to their work and can help detect stress, but only one person thought that chatbots could manage stress in Q3, but when those who were neutral were combined, eight people had a positive or neutral image of chatbots being able to manage stress. The reason for this could be that the chatbots' function is only to measure stress-coping ability, and although they give advice, they do not improve the ability and thus are still at the point where they can manage it.

Table 8 Questionnaire contents

Q.No	Question text	TAM content
1	To what extent do you think the chatbot is useful to detect your stress level/state?	Perceived usefulness
2	To what extent do you think the chatbot is relevant to daily working life?	
3	To what extent do you think the chatbot can manage your stress?	
4	To what extent do you think it is easy to answer the questions from the chatbot?	Perceived ease of use
5	To what extent do you think it is easy to communicate with the Chatbot?	
6	How often did you talk with the chatbot?	
7	To what extent has your experience with the chatbot been positive?	Attitude toward using
8	To what extent did you use the chatbot with confidence?	
9	To what extent were you satisfied with the chatbot?	
10	To what extent do you intend to use this kind of chatbot in the future?	Behavior intention to use
11	To what extent did you agree with the chatbot's assessment of Comprehensibility?	Perceived usefulness
12	To what extent did you agree with the chatbot's assessment of Manageability?	
13	To what extent did you agree with the chatbot's assessment of Meaningfulness?	
14	To what extent did you agree with the chatbot's suggestion?	
15	To what extent did you believe the suggestion by the chatbot was helpful?	

Table 9 Relationship between usefulness and SOC

User No	Q1	Q2	Q3	Q11	Q12	Q13	Q14	Q15	Co	Ma	Me	SoC
(a) Relationship between usefulness and SOC												
1	4	4	3	5	5	5	4	4	Medium	High	Medium	High
2	4	2	3	4	4	4	4	4	High	High	High	High
3	3	4	3	5	5	5	5	5	Medium	High	High	High
4	4	4	5	4	4	4	4	4	Medium	High	High	High
5	4	4	3	4	4	4	4	3	Medium	Medium	Medium	Medium
6	4	4	2	4	4	4	3	3	High	High	High	High
7	3	3	2	4	4	4	4	3	–	–	–	–
8	3	2	2	4	4	4	3	2	High	High	High	Medium
9	4	5	3	4	5	5	5	5	High	High	High	High
10	3	3	2	3	3	3	3	2	Medium	Medium	Medium	Medium
11	2	3	3	4	4	4	4	4	High	High	High	High
12	3	3	3	3	2	2	3	3	Medium	Medium	High	Medium

Group	Q1	Q2	Q3	Q11	Q12	Q13	Q14	Q15
(b) Group analysis								
Positive	6	6	1	10	10	10	8	6
Neutral	5	4	7	2	1	1	4	4
Negative	1	2	4	0	1	1	0	2

83% of the users agreed with the elements of SOC evaluated by the chatbots in Q11 through Q13, while 67% of the users agreed with the chatbot's suggestions in Q14. Regarding whether the support suggestions from the chatbot were helpful in Q15, 50% of the users agreed that they were helpful. This is because we are only proposing support and have not yet reached the point of providing support, which will be confirmed again through experimentation after the support is developed.

Since there were no participants with low-stress coping abilities, it is likely that people with low-stress coping skills would not voluntarily participate in the experiment. Someone declined to participate, but they might be worried that the experiment would stress them out and worsen their condition. One of the issues to be addressed in the future is how to encourage such people to participate in the experiment. Future work will include conducting a pre-survey to assess participants' stress levels,

dividing the cohort into low, medium, and high stress, and evaluating the chatbot with these known cohorts.

As for the use of chatbots, it may become common to use them for monitoring by people who have a high-stress coping ability at the beginning of the current situation. User ID 8 was rated high on all SOC components, but its overall SOC was rated medium. It was medium because the median values of the three membership functions are 0, 0.5, and 1, respectively, and user ID 8's SOC component values are about 0.7. It is halfway between medium and high in the membership functions, resulting in a low value. To avoid this, we need to change the median value in the membership function. On the other hand, if there is only one High element, the overall SOC will be high, but that is not a problem. The difference between a high SOC and a medium SOC is whether the chatbot provides support, but this also needs to be adjusted according to the user's preference.

- User Evaluation of Chatbot Usability (Table 10)

Ease of use was rated highly overall, with 75% of users stating that it was easy to answer chatbot questions and that they were able to use chatbots with positive feelings (Q4, 7, 8). In addition, 92% of the users stated that it was easy to communicate with chatbots (Q5). This is probably because chatbots are now widespread, and people are used to using them. The average number of days of use with chatbots is 4.8 days, which is consistent with the content of Q6, as most users talk with chatbots every day. However, the percentage of those who were satisfied with the use of chatbots was a little low at 58% (Q9), and when asked if they would like to use them in the future, the percentage of those who would like to use them was 33% (Q10). These reasons will be discussed with the feedback later in this section.

- Table of Qualitative feedback, categorized (Table 11)

According to user ID 2, 3, 10, and 11, the chatbots give users the opportunity to reflect on their day, reflect on their accomplishments, and think about areas where they might have done things or behaved differently.

Self-care apps that record emotions or keep a diary are basically meant to give them a chance to reflect, but chatbots could also give them a chance to reflect. This time, the purpose of the SOC was to help people look back and to have them use it continuously, and both were as expected. However, according to the results of Q10, only 33% of the user wanted to continue using it in the future, so it needs to be improved. The duration of the self-care application was 5 days, and the challenge for the self-care application is to get people to continue using it. Therefore, we will consider how to make the chatbot a part of their daily lives.

Not many people wanted to use it in the future because the chatbot asked the same questions to the users every time, as user ID 6 and 7 mentioned. This caused users

Table 10 Relationship between ease of use and SOC

User No	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Co	Ma	Me	SoC
(a) Relationship between ease of use and SOC											
1	5	5	5	5	5	5	4	Medium	High	Medium	High
2	5	5	5	4	4	4	4	High	High	High	High
3	5	5	5	4	5	4	4	Medium	High	High	High
4	5	5	5	4	4	3	3	Medium	High	High	High
5	4	4	4	4	4	4	4	Medium	Medium	Medium	Medium
6	5	5	5	5	5	4	3	High	High	High	High
7	4	4	4	3	3	3	2	–	–	–	–
8	2	3	4	2	2	2	2	High	High	High	Medium
9	5	5	5	5	5	5	3	High	High	High	High
10	2	4	5	4	4	3	3	Medium	Medium	Medium	Medium
11	4	4	5	4	4	4	2	High	High	High	High
12	3	4	2	3	3	3	3	Medium	Medium	High	Medium

Group	Q4	Q5	Q6	Q7	Q8	Q9	Q10
(b) Group analysis							
Positive	9	11	11	9	9	7	4
Neutral	1	1	0	2	2	4	5
Negative	2	0	1	1	1	1	3

Table 11 Categorised user feedback

User No	Category	Impression	Target	Content
2	Usefulness	Positive	Management	It seemed the similar or same questions everyday, but I realized that I could review my day and my feeling through the day at work by using chatbot. Also because of the same or similar questions, I could think today was better/worse than yesterday because ….. to review my feeling and stress level and reason why I'm feeling like this right now is worth to know myself better
3	Ease of use	Positive	SOC questions	I think using the chatbot in the morning is not great because it's best to look back at the whole day. Certain questions are hard to answer by Somewhat or a little, but overall questions were clear
4	Ease of use	Negative	User's reply selection	It might have been more accurate if there was N/A option. Also my answers would have been much different if we weren't in a lockdown or if my kids were at childcare
6	Usefulness	Mix	Algorithm	It's pretty fun to have a taking companion. Being asked the exact same questions everyday can get a bit tiring
7	Usefulness	Mix	Algorithm	Answering exactly same series of questions everyday was a bit tiresome but felt it was quite accurate determining my stress level
8	Usefulness	Positive	SOC questions	The questions asked by the chatbot could be clearer and more targeted
10	Usefulness	Positive	SOC questions	Talking with chatbot created reflection space daily by asking me questions such as new learning or having good sense of work accomplishment, which was very helpful for me to attune to my emotional well being. Probably more questions can be added regarding support that people received at work, or any prompting questions around self care techniques
11	Usefulness	Positive	Management	I'm not sure that it helps to manage stress, but provides an opportunity to reflect & through that, create change if one chooses to do so
12	Usefulness	Negative	Talk skill	More conversational

to get bored with the interaction. It was supposed to ask the same questions to those who prefer the same questions and ask different questions to those who don't, but it asked the same questions to everyone. User ID 8 commented that the questions could be more specific and in-depth, but the questions used this time were mostly superficial. 75% of the users answered that it was easy to answer the questions in Q4, but this percentage would decrease if the questions were more in-depth. Also, since 50% of the users answered that the chatbot was relevant to their work in Q2, this percentage could increase if the questions were more relevant.

The last question on the chatbot was to evaluate the day's conversation, but this did not work well, so the user's preferences need to be reflected in the interaction. For example, the chatbot asks, "How was the conversation today? Even if they answer that it is not good, the same question may be chosen the next day. This is because the question selection method is set to epsilon greedy, but it is necessary to use another algorithm or change the parameters. Although the user's preferences are not known at first, they can be learned through repeated interactions.

Another reason for the small number of people who wanted to use the chatbot in the future may be that, in relation to the opinion of user ID 12, the experiment had little of a chatbot feel to it because it simply answered questions. In order to make it more like a conversation, we are planning to include responses with free descriptions. According to user ID 4, some questions were difficult to answer by simply selecting them, so we think free descriptions can be used.

In addition to personalities, if the chatbots have personas or characterizations, it will be easier to include a small talk in the middle of conversations. In addition, it is not unnatural for chatbots to have more than one persona, so if users can change their personas according to their needs, they will be more inclined to continue using the chatbot.

Conclusion

In the user experience test, we were able to get feedback from 12 working adults who used the system and found areas for improvement. The advantage of this system over others in the past is that it was able to measure stress-coping ability using SOC and suggest support suited to that stress-coping ability, thereby providing stress management for the users. However, this time we showed that the support method is selected by the SOC, but we did not explicitly state that peer support is provided, only that support is provided by a chatbot. If support is to be provided by robots in the future, the use of robots has the disadvantage of being costly. Users found the chatbot easy to install and use, but only one-third of them wanted to continue using it in the future. One of the reasons

may be that the reinforcement learning algorithm does not adapt well to the user's preferences, and the user gets bored. The visualization of stress-coping ability allows users to reflect on their day and find their weak points. Although many users agreed with the stress-coping ability estimated by the chatbot, only about half of them agreed with the idea of managing stress, which may be the reason why few people wanted to continue using the system.

The current occupational stress management system only provides stress checks, and the process is that if there is a problem, the person is referred to a human therapist. However, the number of people with stress has increased so much that therapist appointments have become overbooked, and the support is not reaching those who need it quickly enough. We believe that the ideal system would check stress daily and, at the same time, provide support to improve stress coping skills and the ability to overcome high stress levels. We believe that SOC fits these needs. We are developing this system based on the belief that a robot would effectively provide this support.

Future experiments will be conducted over a longer period of time. However, the current length of time that chatbots have been in use is about 1 month at most for Youper [39], and we believe that one week is the limit for this experiment as well, so we plan to propose a method to enable long-term use. In the case of robots, NICOBO has been developed on the hypothesis that if it lives with the user for more than 3 months, people will become attached to it and live with it forever. [40]. We will focus on personas and develop chatbots with personas. Chatbots can have a variety of personas as their characteristics, and we plan to change them so that communication becomes more var and long-term use is achieved.

In addition, the reason why we could not gather many participants in this experiment was because there was no gratuity and there was a concern that my health might deteriorate in terms of dealing with stress, so we should have emphasized the benefits more to gather many participants.

In this study, we showed that the SOC is helpful in measuring stress-coping ability as a psychological indicator under discussion with a psychologist, but since the relationship between stress management and depression needs to be discussed in the future, it would be better to have a psychiatrist as an expert in psychiatry to discuss the role of robots and chatbots in helping people lead a healthy life. We will continue our research on the functions that chatbots can fulfill to assist people in leading healthy lives.

Appendix

A. Question bank.

Type 1 question is likely to change daily in the SOC and Type 2 is not likely to change much. Type 1 question is used on first and last day of the trial. Type 2 is used every day except for the first day.

Comprehensibility questions.

- Type 1 questions

  - Did you feel your work today was manageable?
  - Was the work you did today structured?
  - Were you clear about the work you did today?
  - Did you find your work today predictable?
  - Were you pleased with how work turned out today?
  - Did you enjoy being in new situations at work today that might have required you to change your established ways of doing things?
  - Did you learn new things in your work today?
  - Did you have a good overall perspective of your work today?
  - Did you have enough time at work today to get things done?
  - Do you have a good overall perspective of the work you need to do tomorrow?

- Type 2 questions

  - Do you feel you are generally in charge of the various situations you find yourself in at work?
  - Do you judge yourself by what you think is important, not by the values of what others think are important?
  - Have you been able to build a home and a lifestyle that is to your liking?
  - Think of the people at work you meet daily, aside from the ones you feel closest to, do you know most of them well?
  - When you face a difficult problem is the choice of a solution always clear to you?
  - When something at work doesn't go your way or according to plan, do you generally find that you are able to keep everything in perspective?

Manageability questions.

- Type 1 questions

– Were you able to influence your work outcomes today?
– Were you able to make decisions in your work today to manage the outcomes?
– Were you able to achieve a positive outcome in your work today?
– Were you able to complete a task or set of tasks today?
– Were you able to independently organize aspects of your work today?
– Did you feel confident and positive about yourself today?
– In general, were you able to manage the tasks at work today?
– Do you feel that you experienced personal development at work today?
– Do you have a good sense of what you were trying to accomplish at work today?
– Did you feel you were on top of all responsibilities at work today?

- Type 2 questions

– Do you like most aspects of your personality?
– Do you have confidence in your opinions?
– In the past, when you had to do something which depended upon cooperation with others, did you have the feeling that it surely would get done?
– In general, can you always find a solution to things in life?
– When you do something that gives you a good feeling on a given day, do these feelings usually go on to last the whole day?
– Do you think that there will always be people whom you'll be able to count on in the future?

Meaningfulness questions.

- Type 1 questions

– Did you find your work today meaningful?
– Do you feel the work you did today was significant?
– Did you find your work rewarding today?
– Were you bursting with energy at work today?
– Were you enthusiastic about some or all of your work today?
– Did you find yourself immersed in your work today?
– In general, did you get along well with the people at work today?
– Will you do interesting things at work tomorrow?
– Did you find your work today interesting?
– Do you feel you had a positive attitude at work today?

- Type 2 questions

– Are you interested in activities that will expand your horizons?
– Do most people see you as loving and affectionate?
– Do you live life one day at a time?
– Do you think about the future?
– Do you think it is important to have new experiences?
– Is it easy to maintain close relationships?
– Do you have a sense of direction and purpose in life?
– Have you improved much as a person over the years?

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Author contributions
AY worked on the research concept, participated in the design and development of the framework, and drafted the thesis. SE served as a design assistant. CC submitted an application for an ethical review of the experiment. NK participated in the research design. All authors reviewed the manuscript draft and revised it critically on the content.

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Availability of data and materials
The data supporting this study's findings are available on request from the corresponding author. The data are not publicly available due to privacy reasons.

Declarations

Ethics approval and consent to participate
Approval was obtained from the Ethics Committee of La Trobe University (HEC19349: Using Technology to Provide Stress Management Support for Working Adults). All participants were informed about the purpose of the study, the anonymity and confidentiality of their results, and provided informed consent prior to participation.

Competing interests
The authors declare that they have no competing interests.

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