Stress Management Design Guideline with Smart Devices during COVID-19

Jeannie Kang[1], Daehee Park[2*]

[1]College of Art and Design, Associate Professor, Ewha Womans University, Seoul, Korea

[2]Samsung Research, Samsung Electronics, Seoul, Korea

Abstract

Background Stress among the general population has been steadily increasing, and the COVID-19 outbreak across the globe amplified stress by changing how we live our daily lives. As the social cost of stress increases and individual lives become devastated, managing stress becomes a critical issue. Government organizations suggest general guidelines to cope with stress during the COVID-19 pandemic. Also, smart devices such as smartwatches and smartphones detect and monitor physiological data as an integral part of our daily life, enabling us to recognize our stress level anytime, anywhere. However, there is a lack of studies regarding stress-relieving methods with smart devices.

Methods We proposed a stress management flow correlating the human cognitive process with smart device interventions. Then, we developed a step-by-step guideline on a smartphone paired with a smartwatch to relieve physical stress with lack of movement, psychological stress with fear from uncertainty, psychosocial stress with loneliness and social isolation, and psycho-spiritual stress with limitations for faith community routine during COVID-19. We recruited 24 university students as participants (8 males, 16 females), and we measured perceived stress scale (PSS) score based on the case study to verify the new design guidelines. The participants ranged in age from 20 to 25 years (mean age = 22.08). We used 14 stress measurement questions to calculate the PSS (PSS maximum = 56). In addition, we used a one-way ANOVA to analyze the PSS results.

Results In general, the results of one-way ANOVA for total PSS indicated a noticeable difference between before and after the prototype ($F = 33.47$; $p < 0.01$). The mean scores were 33.25 before the prototype and 28.13 after the prototype in the statistical analysis. Findings from this study advocated our new design guidelines with smart devices that help relieve stress but there are limitations such as constrained recruiting sample and the duration of the prototype testing, fundamental difference between short-term and long-term stresses, and limited scope of stress categories and smart devices.

Conclusions This study's contribution is to expand smart device's usage to stress relief during COVID-19, not only limited to stress measurement. From this study, we hope to open a discussion on the role of smart devices to manage stress and how to design guidelines for user's quality of life.

Keywords Stress Management, Design Guideline, Wearable Devices, Smart Devices, User Experience, COVID-19

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*Corresponding author: Daehee Park (daehee0.park@samsung.com)

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1. Introduction

Coronavirus-19 (COVID-19) started in late 2019 and rapidly became a global pandemic, dramatically changing our daily lives. Every aspect of our lives has been affected by social distancing such as working from home, learning remotely, online grocery shopping, virtual yoga and psychiatric care visits, video meeting fatigue, and it goes on and. The World Health Organization (WHO) declared COVID-19 as a "Public Health Emergency of International Concern" in early 2020 (Jasarevic et al. 2020). Estimates show that 78% of adults in America experienced the pandemic as significantly stressful (American Psychological Association 2020). Stress is an inability to manage a perceived threat to one's psychological, physical, emotional, and spiritual health (Seaward 2017). Kept in isolation and quarantine leads to a significant level of anxiety, anger, confusion, and stress (Salari et al. 2020). Centers for Disease Control (CDC) has emphasized the need for all individuals to manage stress and protect their mental health during this highly uncertain time.

Therefore, traditional stress coping techniques such as muscle relaxation, breathing, mindfulness and mediations are widely used due to their proven effectiveness. More recently, pervasive smart devices such as smartwatches and wristbands worn on the body 24/7, along with smartphones, help users detect and monitor physiological data as an integral part of daily life, enabling users to recognize their stress levels (Hickey et al. 2021; Krishnamurthi et al. 2021). However, there is a lack of practical studies for relieving stress with smart devices. Thus, we suggest guidelines for designers to apply in developing methods, ultimately helping users measure and alleviate their stress with smart devices.

This paper is organized as follows. First, we reviewed related works on traditional stress measurement, new stress measurement with smart devices, and traditional methods to manage stress (Section 2). Second, we depicted our stress management flow, correlating the human cognitive process based on the Greenberg's stress model and the role of smart devices in-between. Third, we proposed a new stress management design guideline based on the suggested stress flow above (Section 3). Our guideline focuses on how to relieve stress under the key four categories (physical, psychological, psychosocial, and psycho-spiritual) with smart devices. Fourth, to validate the new design guideline, we designed the case study and measured participants' perceived stress scale (PSS) score before and after the prototype testing (Section 4). Finally, we analyzed and discussed the PSS results (Section 5-6).

2. Related Works: Stress Measurement and Relieving Methods

2. 1. Traditional Stress Measurement

The perceived stress scale (PSS) is one of the most widely used psychological tools for stress measurement. Cohen et al. originally developed PSS as a self-reported questionnaire to measure human stress when encountering stressful situations (Cohen et al., 1994). Its general questions, not focusing on specific experience, evaluate how much individuals perceive their life has been unpredictable, uncontrollable, and overloaded during the previous month. There are three versions: PSS-14 is the original version with 14 items, PSS-10 is a shortened version

with ten items, and PSS-4 is for telephone interviews (Lee 2012). Although these methods are widely used, they have limitations in detecting stress levels at the right moment of stress arousal and alerting users to take prompt action.

2. 2. New Stress Measurement with Smart Devices

On the other hand, we have smart devices on our wrists or in our hands almost all day, even while sleeping. Hence, they are advantageous to detect our daily data, including stress levels at the moment of stress arousal, and provide feedback to take necessary action for possibly relieving stress immediately (Hickey et al. 2021; Krishnamurthi et al. 2021). Recently released native health apps from Garmin, Apple, Fitbit, Samsung, and Google provide insight into stress through heartbeats per minute (BPM), heart rate variability (HRV), blood volume pulse (BVP), electrodermal activity (EDA), and skin temperature (ST) (Campos 2019; Sawh 2021). Technologies to detect and monitor stress with smart devices have been improving and play an essential role. There are studies regarding stress measuring and monitoring with smart devices (Smets et al. 2018; Ueafuea et al. 2020) and wearable devices for health behavior changes (Li et al. 2021; Patel et al. 2015; Christmann et al. 2017); there are also limited studies on stress-relieving methods using smart devices (Can et al. 2020; Larsen et al.; 2016).

2. 3. Traditional Methods to Relieve Stress

Government organizations such as CDC and MHF suggested ways to cope with stress during COVID-19 as follows: reviewing your lifestyle (reorganizing and prioritizing, delegating to others, taking duties less seriously), caring body (deep breathing, meditating, healthy meals, regular exercise, restful sleep, awareness of drinking and smoking, vaccination when available), staying away from news and screens, making time for leisure, connecting with people you trust and your community, and lastly, seeking help if needed. Besides government organizations' suggestions, the following techniques are widely practiced due to their proven effectiveness to cope with stress: progressive muscle relaxation (PMR), autogenic training (AT), guided imagery (GI), biofeedback-assisted relaxation (BFAR), diaphragmatic breathing (DB), meditation and mindfulness-based stress reduction (MBSR) to name a few (Table 1).

Table 1 Traditional Stress Relieving Techniques

Technique	Practice
Progressive Muscle Relaxation (PMR)	First identified and developed by Jacobson, tensing and releasing muscle groups through the body to recognize the body's relaxation (McGuigan 1994; Jacobson 1925).
Autogenic Training (AT)	Introduced by Schultz and Luthe, series of mental relaxation exercises to control your body regions over inappropriate physical arousal to fight or flight (Seaward 2017).
Guided Imagery	Imagine/picture objects, scenes, or events (associated with relaxation or calmness) to connect mind and body to achieve desirable consequences (Ackerman and Turkoski 2000).
Biofeedback–Assisted Relaxation (BFAR)	Measure your body's physiological response in real–time from an electronic device (Seaward 2017; Greenberg 2012).
Diaphragmatic Breathing	Most effective relaxation technique due to its accessibility anywhere. Controlled deep breathing from the lower abdomen or diaphragm rather than the thoracic area (Seaward 2017).
Mindfulness–Based Stress Reduction (MBSR)	Stress reduction technique based on the structured mindfulness sequence as a moment–to–moment perception of mental processes (Grossman 2004).
Meditation	Internally focusing one's mind enhances self–awareness, pausing from thoughts, external stimuli to be mentally clear, emotionally calm, and physically healing (Walsh and Shapiro 2006).

3. The New Stress Management Design Guidelines with Smart Devices

3. 1. Development of the Stress Management Flow

First, we developed a stress management flow based on Greenberg's stress model (Figure 1). His stress model proceeds sequentially: 1) out-of-control situation happens, 2) cognitively perceive the situation as stressful, 3) emotionally react to the situation with fear, anxiety, frustration, overwhelmed, and more, 4) physiological arousal occurs with reactions in heart rate, muscle tension, blood pressure, skin temperature, immune system, and more, 5) consequence is stress (Greenberg, 2012).

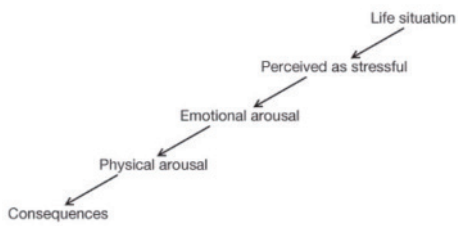

Figure 1 Greenberg's Stress Model (Greenberg 2012)

Based on Greenberg's stress model above (Figure 1), we propose stress management flow with smart devices (Figure 2) as follows: 1) Life situations occur: there are many occasions causing stress in modern life, which is even more prevalent than before due to COVID-19. With the same stressors, people react differently due to their *cognitive appraisa*l (Greenberg 2012, Lazarus and Folkman 1987). For instance, the life situation of losing a job could be perceived as a good opportunity by one person to take a rest and spend more time with family, however, it could be perceived as stressful to another person. 2) Perceived as stress: smart devices perceive the stress levels from sensors once out-of-control life situations occur, and then communicate with users overtly and covertly. Smart watches worn 24/7 detect physiological data through measuring heartbeats per minute (BPM), heart rate variability (HRV), blood volume pulse (BVP), electrodermal activity (EDA), and skin temperature (ST) (Sawh 2021; Smets et al. 2018). 3) Stress awareness: humans are aware of their stress overtly or covertly through smart devices depending on their stress levels. From this cognitively appraised human perception, emotional reactions such as fear, anger, frustration, or overwhelmed arose (Greenberg 2012, Lazarus and Folkman 1987). This emotional arousal brings physiological arousal such as increased heart rates, blood pressure, muscle tension or skin temperature. 4) Efforts to relieve stress: we suggest stress-relieving guidelines to help UX designers develop methods to overcome the COVID-19 related stress using smart devices. Step-by-step guidelines to follow from smart devices become *interventions* or *roadblocks* to prevent a stressor from resulting progressive negative consequences (Greenberg 2012). 5) Stress relieved: smart devices detect decreased stress level after users follow the guidelines. 6) Stress relieved: users recognize their stress is relieved through data from smart devices. Repeated experience reinforce users' learning how to relieve stress. 7) Quality of life: finally, quality of life improves with stress relief as a consequence.

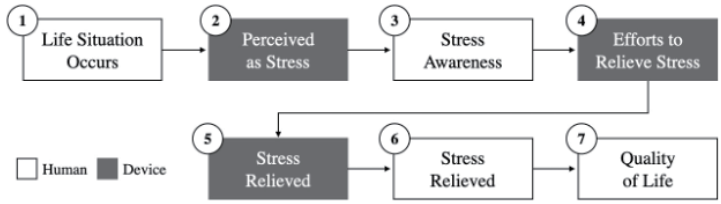

Figure 2 Stress Management Flow with Smart Devices

Along with this proposed stress management flow with smart devices, we developed the guidelines on how to relieve stress with the literature review in the following section.

3. 2. The New Stress Management Design Guideline

We use our stress management flow (Figure 2) as the basis for the step-by-step stress managing sequence with smart devices.

Table 2 The New Stress Management Design Guideline with Smart Devices

Stress Flow	Smart Devices		
Step 1: Life Situation (Human)	There are many occasions causing stress in modern life, which is even more prevalent than before due to COVID-19.		
Step2: Perceived as Stress (Device)	a. Overt Communication: when the smart devices detect high-level stress (stress score: 76-100), it communicates with users directly and instantly.		
	b. Covert Communication: when the smart devices detect medium-level stress (stress score: 51-75), it communicates with users indirectly and subtly.		
Step 3: Stress Awareness (Human)	Depending on their stress levels, humans get informed about their stress status overtly or covertly through smart devices.		
Step 4: Efforts to Relieve Stress (Device)	Category	Stress under COVID-19 & How to Relieve	Smart Device Guideline
	Physical Stress	Lack of movement Exercise: Take care of our body and get moving to lessen fatigue, anxiety, or sadness (CDC 2021; Mental Health Foundation 2017)	Suggest home-based exercise: 1. Take a deep breath 2. Get moving for a minute 3. Stretch for a minute 4. Sit back
	Psychological Stress	Fear from uncertainty Be Mindful: Take time to reflect and practice mindfulness regularly, which can be done anytime, anywhere (Mental Health Foundation 2017).	Suggest well-known methods such as DB, PMR, MBSR, or meditation: 1. Clear minds 2. Take a deep breath 3. Start mindfulness meditation 4. Take a diaphragmatic breathing
	Psychosocial Stress	Loneliness and social isolation Stay Connected: Safely connect with family and friends and get support (CDC 2021; Mental Health Foundation 2017).	Bring back memories from the user's gallery. 1. Bring back photos and videos 2. Show from travels and anniversaries 3. Remind good memories 4. Stay connected.
	Psycho-spiritual Stress	Limitations for faith routine Remote Faith Activities: Communities can still connect remotely and virtually through low and high technologies (World Health Organization 2020)	Suggests daily religious phrases, quiet praying time, and virtual community activities. 1. Quiet minds with hymn songs 2. Read today's religious phrases 3. Commence prayer 4. Share with faith community
Step 5: Stress Relieved (Device)	Smart devices detect decreased stress levels when following the stress-relieving guideline. A stress checklist indicating not-relieved stress as red and relieved stress as green (Park et al. 2018) helps users track their stress status.		
Step 6: Stress Relieved (Human)	People recognize through data from smart devices that their stress is relieved. Repeated stress-relieving experiences reinforce individuals' learning on how to relieve stress more rapidly and effectively.		
Step 7: Quality of Life (Human)	Quality of life improves with stress relief. Conversely, accumulating stress overwhelms one's life.		

• Step 1: Life Situation Occurs (Human)

There are many occasions causing stress in modern life, which is even more prevalent than before due to COVID-19. For example, 78% of adults in America say the coronavirus pandemic is a significant source of stress in their lives (American Psychological Association 2020).

• Step 2: Perceived as Stress (Device)

Once stressful situations occur, smart devices perceive the stress levels from sensors and communicate with users overtly and covertly. Among various smart devices from Samsung, Apple, Garmin, and Fitbit (Samsung 2021; Apple 2021; Garmin 2021; Fitbit 2021), we followed Garmin's stress level system for guideline. It provides a stress scale of 0–25 as resting state, 26–50 as low stress, 51–75 as medium stress, and 76–100 as high stress (Garmin 2021). Smart devices communicate with users directly and instantly as overt communication when they detect a high-stress level between 76 and 100. Overt communication is an apparent and implicit method of communication for users to be informed without explication (Park et al. 2020). On the contrary, smart devices communicate with users indirectly and subtly as covert communication when they detect medium stress between 51 and 75. Covert communication is "subtle, largely nonverbal, and ordinarily unintended" (Rosenthal 2003). Due to possible adverse effects for users to get stressed from information overload, these notifications should be collected on the application's backend and presented once a day or only when requested.

• Step 3: Stress Awareness (Human)

Depending on their stress levels, people get informed about their stress status overtly or covertly through smart devices. Stress awareness via working memory is encoded to the long-term memory and retrieved when similar stress occurs. Thus, users can learn when they get stressed and eventually prevent those situations in the future (Baddeley 1983). Then, the user tries to understand the method to escape the stressful situation by executing some preferred actions (Lewis 2004).

• Step 4: Efforts to Relieve Stress (Device)

There are four types of stressors: physical stress, psychological stress, psychosocial stress, and psycho-spiritual stress, according to Vasantha (Vasantha 2017). Under each category, we defined COVID-19-specific stressors and methods to relieve stress.

a. Physical Stress: One of the stressors during COVID-19 is lack of movement. Restricted physical activity increases the risk to the immune system, causes weight gain from reduced energy consumption, and affects mental health through anxiety, frustration, and depression (Fallon 2020; Lippi et al. 2020). Health experts recommend home-based exercise with simple household items (Fallon 2020), and government organizations urge us to take care of our body and get moving to lessen fatigue, anxiety, or sadness (CDC 2021; Mental Health Foundation 2017). Our suggested guideline to prevent lack of movement is that once the smart device senses less movement, it notifies the user to recognize their activity and suggests several options for home-based exercise alone or remotely together.

b. Psychological Stress: Not only physical stressors but psychological stressors are also significant during the pandemic. Feelings of fear, anxiety, frustration, overwhelm, worry, and stress from uncertainty are prevalent. Therefore, MHF recommends reflecting and practicing

mindfulness regularly, which can be done anytime, anywhere (Mental Health Foundation 2017). Also, widely-practiced techniques such as diaphragmatic breathing (DB), progressive muscle relaxation (PMR), mindfulness-based stress reduction (MBSR), or meditation are beneficial for general psychological health, enhancing positive emotions and quality of life (Grossman et al. 2004). Our suggested mindfulness guideline includes wearable devices that detect heartbeats per minute, heart rate variability, electrodermal activity, skin temperature, and more. We then suggest several well-known stress-relieving methods such as DB, PMR, MBSR, and/or meditation to suit.

c. Psychosocial Stress: Mandatory quarantine and voluntary social distancing to limit COVID-19 infection spread place psychosocial stress and mental health at risk (Hwang et al. 2020) Loneliness and social isolation are intimately associated with stress (Campagne 2019). Government organizations urge us to connect safely with family and friends, get support, and share feelings (CDC 2021; Mental Health Foundation 2017), and others also recommend maintaining social connections with technology (Hwang et al. 2020). Our guideline to prevent loneliness and social isolation is that once devices detect less social activities, the device suggests regular video chats and calls with family and friends. Bringing back memories from previous travel or anniversary photos in their photo gallery is another way.

d. Psycho-spiritual Stress: Limitation for faith community routine due to social distancing from COVID-19 is psycho-spiritual stress. Individuals with a positive spiritual identity cope with stress more efficiently and have strong immunity to stressful situations with spiritual beliefs, which are a source of support, hope, meaning, and purpose of life (Graham et al. 2001; Koenig 2010). The WHO recommends remote faith activities because communities can still connect remotely and virtually through low and high technologies (World Health Organization 2020). Our guideline to prevent psycho-spiritual stress is that once devices detect users are apart from faith community routine, the device suggests daily religious phrases, quiet praying time, and virtual community activities.

• Step 5: Stress Relieved (Device)

If users follow the guidelines above, then smart devices detect decreased stress levels. Based on our literature review, individuals can effectively ease their stress following wearable devices' breathing-regulating app and vibration transmitted to their wrist (Yamane 2021). Also, a stress checklist indicating "not-relieved stress" as red and "relieved stress" as green (Park et al. 2018) helps users track their stress status.

• Step 6: Stress Relieved (Human)

People recognize through smart device data that their stress is relieved. Stress-relieving experiences reinforce human learning on how to relieve stress more rapidly and effectively. People eventually get out of their stressed state faster through this process by using their working and long-term memory (Baddeley 1983).

• Step 7: Quality of Life (Human)

Finally, people experience improved quality of life through stress relief. Accumulating stress overwhelms one's life. Therefore, early stress awareness and attention can enhance the quality of life and eventually impact a person's lifespan (Cushway 1996).

With stress management flow correlating human cognitive processes and smart devices'

interventions, we suggested COVID-19 related the new stress management guidelines under four stress categories. The guidelines aim to help UX designers create methods for overcoming COVID-19-related stress using smart devices. In the following section, we present a case study.

4. A Case Study for Stress Management Guidelines Using Smart Devices

This case study is based on *The New Stress Management Design Guideline with Smart Devices* (Table2) as follows. We assume stressful life situation happens (Step 1 in Table 2) and smartwatch detects high-level stress between 76 and 100 and overtly communicates with users (Step 2-a in Table 2). Not tested in this case study, however, once the smartwatch detects medium-level stress level between 51 and 75, it covertly communicates user for the possible adverse effects (Step 2-b in Table 2). Users are aware of their stress level through the smartwatches' notification (Step 3 in Table 2) then decides to pair their smartphone to manage their stress (Figure 3). Stress was classified into 4 types (physical, psychological, psychosocial, and psycho-spiritual) based on the research (Vasantha 2017). After following step-by-step stress-relieving methods in each stress category on the smartphone (Step 4 in Table 2, Figure 5-8), smartwatch detects stress relieved (Step 5 in Table 2, Figure 3). Details for participants, materials, description of user interface, and overall procedure are illustrated in the following sections.

4. 1. Participants and Materials

We recruited participants using an online survey gauging their recent physical, psychological, psychosocial, and psycho-spiritual stress from COVID-19 on a scale from "0" (*not at all*) to "4" (*very often*). From the survey participants, we chose 24 participants and assigned six participants to each stress category based on those who responded as stressed "often" (scale 3) or "very often" (scale 4) in specific stress categories. Prototype testing was done in person for an hour per each person. Each participant was asked to answer perceived stress scale (PSS) with 14 questions before the testing. Participants who had high physical stress in the recruiting survey were asked to use a mobile prototype designed to relieve physical stress. Then we measured PSS-14 after the testing. The other stress responders were subjected to related stress prototype testing.

Apple MacBook, iPad, iPhone, and Apple Watch were used for case study testing. We prepared three static prototypes for Apple Watch indicating a) stress-detection status, b) mobile-pairing notification to relieve stress, and c) stress-relieved status (Figures 3-4). Detecting a participant's stress level directly from the smartwatch on their wrist on the spot would be more accurate. However, to do so would require making a stressful situation for prototype testing. To avoid ethical issues, static prototypes were substituted for actual measurements, showing stress variations. We prepared high-fidelity smartphone prototypes (Figures 5–8), one for each stress category, with Adobe XD indicating step-by-step stress-relieving guidance. We describe the detailed user interfaces in the following section (Section 4.2).

Figure 3 Stress Detection on Smartwatch

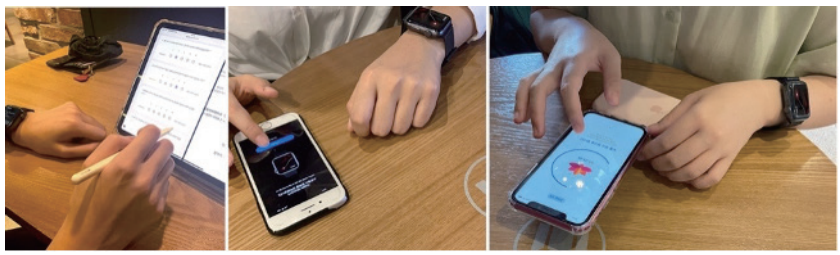

Figure 4 Participants Taking Prototype Testing

4. 2. Descriptions of User Interfaces

• For Physical Stress with Lack of Movement

Once a participant's physical stress is detected, a stress-detection interface appears on the watch (Figure 3). Then, a paired smartphone application launches and urges users to start relaxing their stress (Figure 5). A step-by-step guide to relieve physical stress includes taking a deep breath, moving the body for a minute, stretching for a minute, and then sitting.

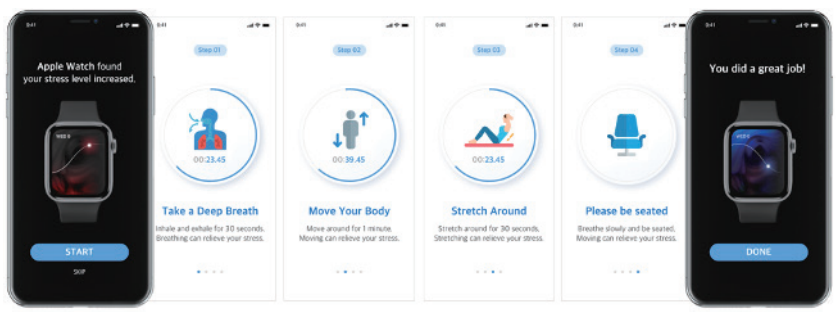

Figure 5 Physical Stress Relieving User Interface

• For Psychological Stress with Fear from Uncertainty

Once a participant's psychological stress is detected (Figure 3), a paired smartphone application launches, urging the user to follow a step-by-step guide to relieve their psychological stress (Figure 6). Instructions include clearing their minds, taking a deep breath, starting mindfulness meditation, followed by more diaphragmatic breathing.

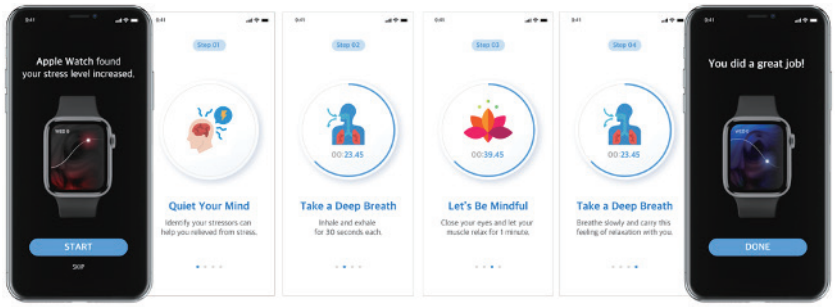

Figure 6 Psychological Stress Relieving User Interface

• For Psychosocial Stress with Loneliness and Social Isolation

Once a participant's psychosocial stress is detected (Figure 3), a paired smartphone application launches and urges the user to follow a step-by-step guide to relieve psychosocial stress (Figure 7). The steps include bringing back users' precious memories with family, friends, and pets from traveling, special anniversaries, and reminding users that they are not alone. In addition, they can make a video call or send messages to stay connected.

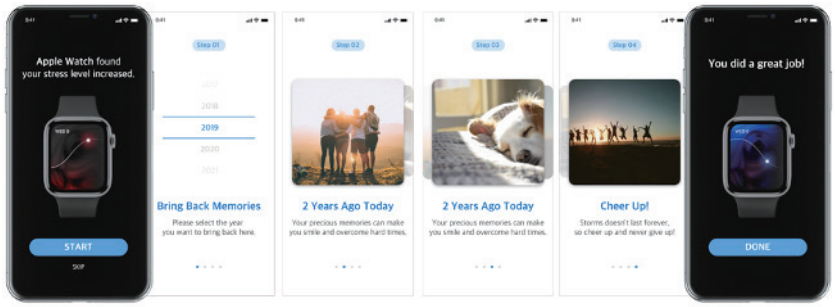

Figure 7 Psychosocial Stress Relieving User Interface

• For Psycho-spiritual Stress with Limitations for Faith Community Routine

Once a participant's psycho-spiritual stress is detected (Figure 3), the paired smartphone application urges users to follow a step-by-step guide to relieve their psycho-spiritual stress (Figure 8). Guidelines include commencing prayer with ambient sound, suggesting religious phrases, and sharing feelings and thoughts with the faith community.

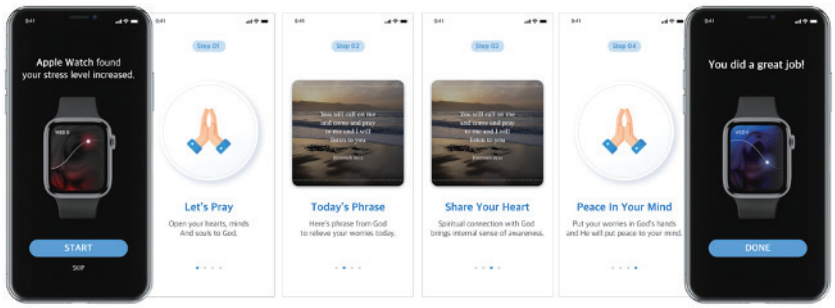

Figure 8 Psycho–spiritual Stress Relieving User Interface

4. 3. The Case Study Procedure

The case study procedure designed as a within-subject experiment (Figure 9). In the initial stage, we introduced the purpose of the case study and the procedures. In the next stage, we asked participants to measure stress degrees with the PSS-14 questions when encountering stressful situations. In the following stage, prototype testing was conducted to relieve detected stress with guidelines on paired smartphones. Then, participants answered the same PSS-14 questions to measure any changes in stress degrees. In the last stage, participants answered all demographic questions.

Figure 9 The Case Study Procedure

5. Results

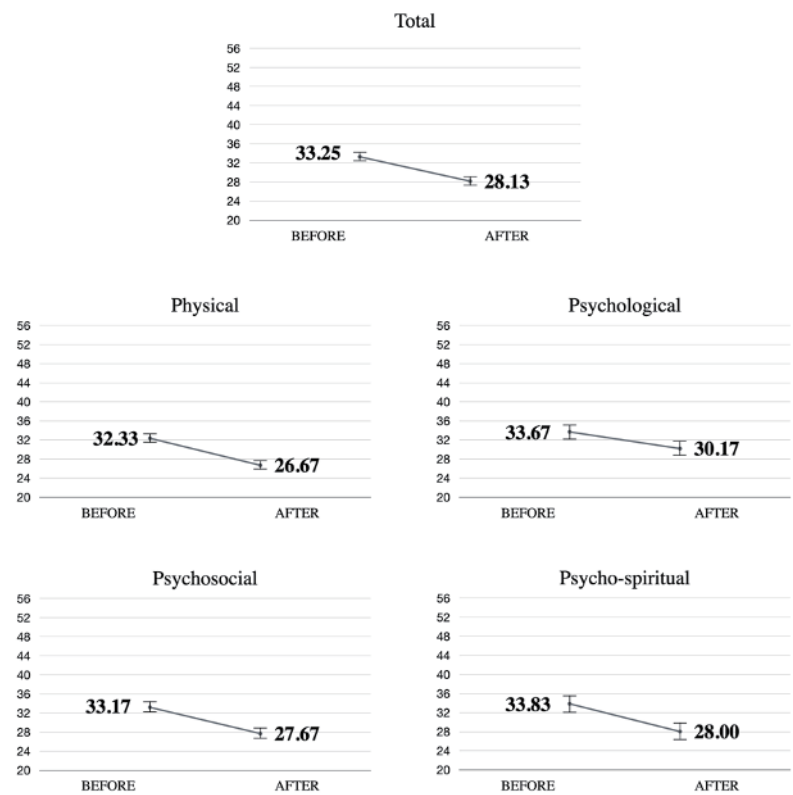

Figure 10 The Result of One-Way ANOVA Analysis

We recruited 24 university students as participants (8 males, 16 females), and assigned six participants to each stress category prototype testing based on their stress category during the recruiting. Participants who had high stress in a specific category were asked to follow

step-by-step stress relieving prototypes designed for that stress category. We compared PSS-14 scores before and after each prototype testing. The participants ranged in age from 20 to 25 years (mean age = 22.08). We used 14 stress measurement questions to calculate the PSS (PSS maximum = 56). In addition, we used a one-way ANOVA to analyze the PSS results. In general, the results of one-way ANOVA for total PSS (Figure 10) indicated a meaningful difference between before and after the prototype ($F = 33.47$; $p < 0.01$). The mean scores were 33.25 before the prototype and 28.13 after the prototype. They were noticeably lower than before the prototype in the statistical analysis. Regarding physical stress state (Figure 10), the mean scores were 32.33 before the prototype. In contrast, the mean scores after were 26.67. Thus, they were noticeably lower than before the prototype ($F = 18.29$; $p < 0.01$). Regarding psychological stress state (Figure 10), the mean scores were 33.67 before the prototype and 30.17 after the prototype. There was no significant difference between them ($F = 2.62$; $p = 0.14$). Regarding psychosocial stress states (Figure 10), the mean scores were33.17 before the prototype. Otherwise, the mean scores were 27.67 after the prototype. There was a noticeable difference between them ($F = 20.55$; $p < 0.01$). Finally, regarding psycho-spiritual stress state (Figure 10), the mean scores were 33.83 before the prototype and 28 after the prototype. There was a distinguishable difference between them ($F = 6.86$; $p < 0.05$).

6. Discussions

Although detecting stress with smart devices has been improving and plays a vital role, there is a lack of design guidelines for relieving stress with smart devices. Hence, we set up a stress management flow correlating human cognitive processes and smart devices' interventions to address this issue. Then we proposed COVID-19-related stress management guidelines with smart devices. We demonstrated the effectiveness of our guideline through a case study by comparing PSS before and after prototype testing with 24 university students. As a result of one-way ANOVA for total PSS between before and after, we found stress scores difference in general.

Regarding physical stress states due to lack of movement during COVID-19, we guided participants to exercise through step-by-step user interfaces, which decreased stress scores from 32.23 to 26.67. Regarding psychological stress states due to fear of uncertainty, we guided participants to be mindful through step-by-step user interfaces, which reduced stress scores from 33.67 to 30.17 but still reflecting a high-stress state. We suggest that researchers could lower this psychological stress score by administering this test to different age groups such as seniors. Different ages have different stressors, coping strategies, and positive/negative affect (Chen et al. 2018). Regarding psychosocial stress states due to loneliness and social isolation, we guided participants to stay connected through step-by-step user interfaces, which decreased stress scores from 33.17 to 27.67. Finally, regarding psycho-spiritual stress states due to limitations on faith community routines, we guided participants to take faithful activities remotely through step-by-step user interfaces, which reduced stress scores from 33.83 to 28.

Results of our case study validated the effectiveness of our COVID-19 related stress-relieving design guideline with smart devices. However, researchers should interpret our results with

constraints in mind. First, the recruiting sample for the prototype testing was a convenience sample and may not represent the entire population. Our result from 24 university students whose mean age was 22.08 may not be generalized to other samples. Further studies are needed with larger number of users with various age groups. Second, the duration of the prototype testing was short, and results may be different with longer durations. If we could perform testing for a longer period of time, preferably real-time at user's everyday life, noticeable things might be found. Third, related with the previous limitation, short-term stress measured by smartwatch is not fundamentally same as long-term accumulated stress. Interpreting 'stress' measured by physiological data on smartwatches could be limited when we directly connect them with the concept of traditional 'stress'. Fourth, the scope of this research is limited to four stress categories (physical, psychological, psychosocial, and psycho-spiritual) and two smart devices (smartwatches for detecting stress and smartphones for relieve stress). Stress category might be a lot more complicated and there are numerous smart devices we could utilize to detect and relieve stress.

There are several directions for future work. First, further research about ambient intelligence and machine learning is required to be aware of the user's stress context holistically, classify stressors in real-time, and predict and prevent stressors beforehand (Aztiria 2017). Second, we need to monitor how stress levels change from detection to relief for a longer period of time. Stress is a state of not managing a perceived threat to one's psychological, physical, emotional, and spiritual health (Seaward 2017). Therefore, detecting and monitoring for a longer time through various methods on top of smartwatches and smartphones is necessary to manage perceived threats to one's health. Last, we need to expand our exemplified design guidelines to other stress categories and elaborate our stress-relieving guideline steps in each category.

7. Conclusions

The COVID-19 outbreak amplified our already steadily increasing stress among the general population. Managing stress becomes a critical issue as lives become devastated and the social cost of stress increases. Thanks to smart devices, detecting and monitoring our physiological data 24/7 enables us to recognize our stress level anytime, anywhere. This study's contribution is to expand smart device's usage to stress relief during COVID-19, not only limited to stress measurement. In this extended usage, we proposed stress management flow correlating human cognitive processes and smart devices' interventions, followed by stress management guideline with smart devices for physical, psychological, psychosocial, and psycho-spiritual stress categories. Findings from this study advocate our new design guidelines with smart devices that help relieve stress but there are limitations as well. From this study, we hope to open a discussion on the role of smart devices to manage stress and how to design guidelines for the quality of life.

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