

Master's Thesis

**Promoting Behavior Change Through
Interactive Signage with Active Talk Function**

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Abstract

The recent widespread of smartphones and smartwatches have brought many healthcare applications which utilize the powerful sensors such as accelerometer, a heart rate monitor, etc. and study has been conducted in Europe and US to use information technology as a treatment of lifestyle diseases. Lifestyle diseases (e.g. obesity, hypertension, etc.), as the name implies, are usually caused by improper lifestyles. As a treatment, it is necessary to review people's daily life pattern and lead them to a better lifestyle, which is called behavior change in the medical field. Currently, many pieces of research and developments on behavior change have been conducted. From the viewpoint of cost and information reachability, the information system of the most studies is developed as mobile applications. However, this approach has a problem with sending triggers for inducing behavior change. Therefore, more alternative approaches are needed to improve the efficiency of digital interventions and both inducing behavior change and maintaining the result.

In this thesis, we propose and construct an interactive signage system, which actively talks to the passing persons to induce his/her behavioral changes through visual and auditory stimulation. We design our proposed system based on the Persuasive System Design (PSD) Model and the Behavior Change Support System (BCSS) theory. The design consists of 4 parts: recognizing (identifying and classifying users), executing (sending triggers and inducing behavior change), reviewing (recording users' reaction), and feedback (keeping or improving users'

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motivation). As a method of tracking users' status and performance, we use the smartphone and the smartwatch to collect users' biometric data (e.g. heart rate, number of steps) and users' location. To send the user triggers continuously without being interrupted by notifications from other applications, we set the interactive signage in the daily action line of users and present information to users when they pass the signage. In order to make the system more persuasive, we pick up 8 features from the 28 feature list of PSD and apply them to our design.

We developed a prototype of our system and deployed 4 signages in our lab. To investigate users' reaction to the interactive signage system, we conducted a 3-week experiment with 15 participants. Through the result, we found that our system can induce low time and labor cost behavior change effectively. Based on the result of the experiment, we updated our interactive signage system by adding response time (the time passed from showing contents until the user responds) record function and voice feedback function. Furthermore, to collect the data of response time which is considered as a part of users' reactions, we conducted an additional experiment with the same participants in the previous experiment (except for 1 missing participant) for 1 week after updating the system. In the additional experiment, the participants were not asked to respond to the utterance definitely. As a result, it is shown that the behavior change by the proposed signage is still effectively induced. Finally, we also analyzed the relationship between the passed time and the response rate of each task type. The result shows that the number of ignorance of Personal Task and Check Task does not rise even as the time passes.

Keywords:

Persuasive System Design, Behavior Change Support System, Beacon, Interactive Signage, Human-Computer Interface

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1. Introduction

With the progress of information and communication technology in recent years, many Internet of Things (IoT) devices have been spreading in our daily lives. At the same time, due to the sophistication of Artificial Intelligence (AI) technology, we can recognize people's behavior with better accuracy and make the human-computer dialogue more natural. The smart devices using IoT and AI technologies are usually equipped with powerful sensors like accelerometer and heart rate monitor, which makes it convenient to achieve versatile functions by installing applications. Based on this background, many research and developments related to behavior change have been conducted. Behavior change is also often called persuasion, meaning "reinforcing, forming or altering a user's attitude or behavior or an act of complying without coercion and deception" [1]. In the medical field, behavior change is the process that reviews patients' daily life patterns and tries to lead them to a better lifestyle. Therefore, people take behavior change as a treatment of lifestyle disease which is usually caused by an improper lifestyle. A classical way for inducing behavior change is to conduct counseling and preach the importance of treatment and future risk. For example, users can be asked to measure weight or the amount of sugar ingested and record the result every day. However, forgetting to record the data or unwillingness of the user can cause problems for the continuity of this method. To cope with this problem, a lot of research and development to promote behavior change by using information technology have shown up. For instance, Sankaran et al. have proposed a telerehabilitation application which induces Coronary Artery Disease (CAD) patients to comply with the treatment plan and prevent disease recurrence [2]. In the management of smoking cessation, hazardous drinking, obesity, diabetes, asthma, tinnitus, stress, depression, and insomnia, positive results have also been obtained [3]. Therefore, the information-technology-based method enabling behavior change is also considered as Digital Medicine and have been extensively studied in Europe and the U.S. [4].

Not only in the medical field but also many examples exist in other areas. For example, Pokémon Go is an augmented reality game, and it has been shown that Pokémon Go can serve as a behavior change support system in increasing players' physical activity [5]. Consolvo et al. developed an application, where a user's

physical activity leads to a more beautiful and growing virtual garden [6]. Some researchers have used additional sensors and equipment for promoting behavior change such as nurturing a healthy lifestyle like, exercising more or drinking more water. For instance, Fortmann et al. developed a bracelet with embedded LEDs to improve users' drinking behavior [7].

Most of these developments are designed to help people with improving users' lifestyle or maintaining their improvement. Also, due to the cost and information reachability, the information systems of the most studies are developed as mobile applications, especially nowadays people practically always carry their smartphones which make it possible for researchers and developers to collect personal data and sense the environmental context through the mobile application. However, this approach has a problem with sending triggers. The trigger means the information sent to the user for stimulating users' senses and trying to induce a behavior change. The trigger usually used in the existing system is text messages, and the way for sending the trigger to users is using push notification. A notification pushed in a proper timing can attract users' attention and lead users to open the application so that the user can process the information inducing behavior change. However, users nowadays receive a vast number of notifications from various apps that it all too often interrupts the users and it may diminish noticing triggers from behavior change apps. Also, when users are end-up turning their phones into a silent mode in which they do not receive push messages, many of the messages may remain unnoticed. Namely, this approach has a problem with sending triggers.

Moreover, the mobile-application-based methods often used in current systems like the reminder, social competition, and self-monitoring, may have weak points which affect the quality of behavior change apps. Even if an app may induce behavior change successfully, it is hard to maintain the effect due to the limitations of the methods based on mobile apps. Therefore, we need alternative approaches for improving the efficiency of digital interventions and both inducing behavior change and maintaining the result.

To resolve these problems of mobile application side, we propose here a design of an environment for inducing behavior change with the cooperation of behavior change support system (BCSS). This technological environment means an en-

closed place where people spend a long time (e.g., a company, a university or an elder care center) equipped with smart devices for inducing and maintaining behavior change. In our design, both the user side and environment side are included for analyzing a user's status and presenting user-related information to the user. In the user side, we use the smartwatch and smartphone to collect user's data (e.g., heart rate, number of steps). In the environment side, we use the interactive signage with an active talk function and deploy the signage in the daily action line of users. By using the active talk function, we can send visual and auditory stimulation to users. By setting the device in the daily action line, it can recognize the daily patterns of users and continuously send triggers to users. We also consider this environment as a small society. Therefore, the target of this environment is not only a single individual but also a group, and we apply social support to this design with careful consideration of users' privacy and social relationship.

Based on the BCSS theory [1], there are four parts in our design: recognizing, executing, reviewing and providing feedback:

- The Recognizing Part is for identifying users and understanding users' needs, goals, past performance and current progress. According to the theory of goal setting, people with high self-efficacy set higher goals and have higher performance than people with low self-efficacy [8]. It is necessary to change the content of triggers based on the user's type. Therefore, in the recognizing part, we estimate the type of user based on user's performance and progress.
- The Executing Part is the part where we send triggers to the user and try to induce a behavior change after we divide users into groups. The triggers contain user-related information (e.g., name, weight) and social-related information (e.g., a ranking of performance and contribution of other members).
- The Reviewing part is for checking users' progress.
- The Providing Feedback part is for encouraging users and improving the motivation based on the result of the reviewing part.

By applying the design of behavior change environment, as long as people are staying in this environment, our system is expected to be able to send stimulation to users and promote behavior change continuously, so that we can improve the efficiency of digital intervention and the quality of behavior change.

To investigate the effectiveness and usefulness of our proposed design in inducing behavior change, we developed a prototype of our design and deployed 4 interactive signages in our lab. In the prototype, our interactive signage can identify users through Bluetooth signal emitted from BLE beacons carried by users. After identifying, the signage sends triggers to the user by sending voice and text message, and users can respond to the message through the touch panel of the signage. Once the signage receives a response, it sends feedback. If the signage does not get any response, it returns to the initial screen and restart observing the Bluetooth signal. To investigate the answer of 3 questions: first, whether users respond to the message from the interactive signage or not; second, whether users provide their personal data to the interactive signage or not; third, whether the interactive signage can induce a behavior change, we held a 3-week experiment with 15 participants. The participants were asked to carry a BLE beacon with them while staying the laboratory during the experiment. In the experiment, we prepared five types of dialogue scenarios: Personal Task (collect personal data from the user), Check Task (confirm the state of other members or equipment), Personal+ Task (particular personal task that has next action tasks), Check+ Task (particular check task that has next action tasks), Action (combined with Personal+ Task and Check+ Task, try to promote a particular behavior). In order to compare the difference between the ideal environment and the real environment, all the participants were asked to respond to the utterance from the interactive signage whenever they hear the voice message during the first (period with bias) and after the first week, they do not need to respond to the task definitely to eliminate the bias (period without bias).

During the experiment, we collected a total of 2447 responses, of which 18 responses were rejection, and 337 responses were ignorance. The average number of responses for each participant was 61.1 during the first week and 78.3 during the next two weeks. The response rate of the participant to each task type was 84.35% (Personal Task), 83.33% (Personal+ Task), 85.18%(Check Task),

86.67% (Check+ Task), and 88.24% (Action Task) during the next two weeks. The response rate of Personal Task and Personal+ Task shows that our system can collect personal data without coercion to a certain degree. As a result of analysis by time zone during the next two weeks, it reached the highest response rate between 8:00–10:00 and the lowest response rate between 15:00–16:00. The reason for this is considered as that participants was getting busy in the afternoon, or they had answered many inquiries and got bored.

Moreover, the response rates of the signages set in the turning corner of the corridor and the desk box were 85.63% and 88.17%, indicating that the positions were suitable for our purpose. On the other hand, the response rate to the inquiries from the signage set in the rest space and the coffee space was 61.72% and 89.72%. The reason for the low response rate in the rest space can be the participant might be sleeping, and our system could not identify participants' status then published the inquiry by accident. After the experiment, all participants were asked to answer a questionnaire, and we obtained the result from 14 people. In the questionnaire, participants were asked to answer their feelings about the frequency and timing of inquiry, impressions about tasks and the utterance function. As a result of the question about participants opinions to the voice message function, 9 people reported that it was fascinating to hear the voice message and 4 people reported that the function could remind them to respond. Based on the above results, we confirmed that the utterance function could raise users' attention with a high probability. Through the result of the response to Check Task, we also found that interactive signage can effectively induce low labor and time cost behavior change.

In order to collect the response time (the time passed from showing task until users respond), which is also a part of users' reactions, we updated our interactive signage system based on the result of the experiment and did an additional experiment with the same participants (as experiment 1, except 1 missing participant and 1 participant went to a business trip) for 1 week. The updated system could record and upload the time passed after the last response of the user, to investigate the relationship between response time and task, location, and time zone. Also, the system can give voice message as feedback to the user after they respond to tasks which intends to give user more interactivity and

promote them to respond to the tasks more. In this experiment, we changed the rule of presenting the Check Task from “Independent for each user” to “Once 1 user does it, it won’t be presented to other users again until the cooldown is finished.” to reduce the burden of users. The result of this experiment supported the correctness of the conclusion we got from the previous experiment.

During two experiments, we have collected many records of ignorance. For promoting behavior change effectively, it is essential to figure out the reason of ignorance, and we deduce tiredness as a high possible reason. We believe user’s motivation for responding to the system decreases over time in the long term, which increases tiredness as well as ignorance to the trigger. To verify the correctness of this guess, we analyzed the records of tasks during the whole experiment period. Moreover, due to the type of tasks is also a variable, we analyzed all the records by each task type to investigate the relationship between the response result of each type of task and the time passed. As a result, we found that the amount of the ignorance to the Personal Task and Check Task didn’t significantly increase over time.

The rest of this thesis is organized as follows. The existing work related to this thesis is provided in Section 2, and Section 3 presents our proposed system architecture. Section 4 includes the description of the experiment for investigating the effects of our prototype system, the result of experiment and discussion. Section 5 describes the additional experiment, the result of experiment and discussion. We discuss the effective area of our system in Section 6. Finally, Section 7 concludes this thesis.

2. Related Work of Behavior Change Support System (BCSS)

2.1 The Definition of Behavior Change Support System

A behavior change support system is defined as “a sociotechnical information system with psychological and behavioral outcomes designed to form, alter or reinforce attitudes, behaviors or an act of complying without using coercion or deception” [1]. In our research, we design an environment for inducing behavior change based on the Persuasive System Design (PSD) model [9] and the Behavior Change Support System (BCSS) theory [1].

2.2 Persuasive System Design

Interactive information technology designed for changing users’ attitudes or behavior is known as persuasive technology [10]. In Fogg et al.’s research, a framework providing a useful method for understanding persuasive technology has been developed and widely utilized in many developments. However, Oinas-Kukkonen et al. argued that the framework was too limited to be applied directly to persuasive system development and/or evaluation [11]. To discuss the process of developing and evaluate persuasive systems as well as describe the content and software functionality in the final product, Oinas-Kukkonen et al. proposed the Persuasive System Design model [9]. The persuasive system may be defined as “computerized software or information systems designed to reinforce change or shape attitudes or behaviors or both without using coercion or deception” [9]. In the PSD model, there are three steps for developing a persuasive system: understanding key issues behind persuasive systems, analyzing the persuasion context, and design of system qualities.

2.2.1 Understanding Key Issues Behind Persuasive Systems

In the first step, understanding key issues behind persuasive systems, Oinas-Kukkonen proposed seven postulates that need to be addressed when designing or evaluating persuasive systems:

1. Information technology is never neutral: It means that we are living in an environment where is full of information technology and we are always persuading or persuaded in this environment.
2. People like their views about the world to be organized and consistent: If systems support the making of commitments, users will more likely be persuaded.
3. Direct and indirect routes are key persuasion strategies: Persuading people by showing contents and letting people process the information is called “direct route”. And the persuasion through cues or stereotypes is the indirect route.
4. Persuasion is often incremental: It is necessary to divide the big task into smaller tasks and lead people to finish them incrementally.
5. Persuasion through persuasive systems should always be open: Unclear system makes reduce the persuasiveness of contents or end up misleading users.
6. Persuasive systems should aim at unobtrusiveness: Persuasive system should not be annoying and disturbing users while they are performing their primary tasks with the aid of the system.
7. Persuasive systems should aim at being both useful and easy to use: A system which useful but hard to use and a system which is useless can hardly attract users’ interest and lead users to use the system.

Through these postulates, we can understand there are 3 essential elements in designing a persuasive system: the goal of persuasion (the intent), the information about users’ status (the event), and the way for presenting the information (the strategy). While addressing these elements, we should also keep the easy usage and unobtrusiveness of the system to maintain users motivation of using the system. The details of these elements have been described in the next step, analyzing the persuasion context.

2.2.2 Analyzing the Persuasion Context

There are three parts in the second step, analyzing the persuasion context: intent, event, and strategy.

The intent determines the change type, primarily whether the persuasion aims at the attitude and/or behavior change. It may be easy to promote one-time behavior change (e.g., answer a question, switch off a switch), whereas permanent behavior change (e.g., quit smoking, quit alcohol) is much more difficult. An attitude change that directs behavior may be the most difficult to achieve [9]. Due to the differences of individuals (e.g., emotions, beliefs, experience), users' attitude can be varied in many ways which make it difficult for inducing an attitude change. Therefore, it is necessary to decide the target group and issue in the first stage.

The event determines the use context and user context of the system. For example, many persuasive systems have been developed for promoting health and well-being. The users of these applications often have the necessary information to act and, in many cases, they even have the proper attitudes, but they have problems in behaving in line with them. People who have a high need for cognition tend to follow the direct route to persuasion whereas people have a low need for cognition may influence their information processing [9]. Therefore, it is necessary to understand users' status such as needs, goals, current process, past performance, and so on.

The strategy determines the message and route of sending triggers to users. Persuasion relies primarily on symbolic strategies that trigger the emotions, and a persuasion situation may be defined as an event in which the persuadee makes optimal compromises among conflicting forces [9]. Therefore, what kind of information (message) need to be sent to the user and how to send the information (route) is an integral part of persuasion.

2.2.3 Design of System Qualities

There are mainly four categories in this phase: primary task, dialogue, system credibility, and social support. Each category has seven software features, and each feature has its effect. However, it doesn't mean designers need to apply all of them to their design but only the necessary feature depending on their needs.

The contents of these features have been summarized in Table 11-14 in Appendix A-D.

2.3 BCSS Theory

Behavior Change Support System (BCSS) Theory [1] is an extended version of Persuasive Systems Design (PSD) [9]. BCSS theory emphasizes the practical behavior change outcome and lists a set of software features for the BCSS. In this theory, Harri Oinas-Kukkonen proposed an Outcome/Change (O/C) matrix based on the intended outcomes and the types of change for helping design and research. The O/C matrix shows the three potential outcomes with three change types that formation, alteration or reinforcement of attitudes, behaviors, or complying. The contents of O/C matrix have been summarized in Table 1.

Table 1. Outcome/Change Design Matrix

	C-Change	B-Change	A-Change
F-Outcome	Forming an act of complying (F/C)	Forming a behavior (F/B)	Forming an attitude (F/A)
A-Outcome	Altering an act of complying (A/C)	Altering a behavior (A/B)	Altering an attitude (A/A)
R-Outcome	Reinforcing an act of complying (R/C)	Reinforcing a behavior (R/B)	Reinforcing an attitude (R/A)

2.3.1 Outcomes

A forming outcome (F-Outcome) means the formulation of a pattern for a situation where one did not exist beforehand, for example, starting jogging every day. An altering outcome (A-Outcome) means changes in a person's response to an issue, for example, increasing the amount of exercise, decreasing the amount of alcohol, or quitting smoking. An increase and decrease in behavior are related to frequency, intensity, or duration of the behavior. Stopping a behavior can also be taken as a formulation of new behavior (F-Outcome). A reinforcing outcome (R-Outcome) means the reinforcement of current attitudes or behaviors, making them more resistant to change [1].

2.3.2 Changes

With a C-Change, the goal of the behavior change is making sure that the end-users comply with the request of the system. For example, in health care applications, the common goal can be guaranteeing patients take medicine every day. The goal of B-Change is to elicit a more enduring change than simple compliance once or a few times. For example, using a stair instead of the elevator, eating more vegetable, and so on. The goal of systems supporting an A-Change is to influence the end-users' attitudes rather than behavior only. For instance, changing a smoker's attitude to the cigarette. The changes are not exclusive to each other. In some cases, the behavior change support system aims both an A-Change and a B-Change simultaneously. This is particularly important in areas such as providing support for overcoming addictive behaviors so that the users who are in spite of high motivation and proper attitudes may lack the skills can put their knowledge and attitudes into practice (a B-Change is needed), but at the same time, their self-efficacy may need further strengthening (an A-Change is needed) [1].

2.4 Examples of Existed BCSS

Many research and development for improving peoples' life patterns and maintaining the result of improvement, many research and developments utilizing IoT and AI technology have been conducted, and the number is still increasing. Moreover, the approaches used for inducing behavior change are quite versatile.

Gamification has become popular recently since it can affect players' attitudes and behaviors through playfulness. Gamification may contain many attractive elements, and it may succeed to keep players' motivation in using the application. To increase the activity of users, for instance, Consolvo et al. proposed an application embedding gamification in which the users' physical activity leads to a more beautiful and growing virtual garden [6]. Another famous BCSS example using gamification is Pokémon Go. It is an augmented reality exergame and has been shown to be able to serve as a BCSS [5]. The game can influence behavior on all three levels as it can form, alter, reinforce behaviors [1] and successfully add activity in players' life, enhance routines, exploration, increase physical activity,

strengthen social bonds, lower social barriers, increase emotional expression and self-treatment [5].

Social support is another popular approach used in current BCSSs. It isn't a single feature but including learning, comparison, competition, normative influence, facilitation, cooperation, and recognition [1]. Under the influence of social relationship and peer pressure, even people with low self-efficacy and low motivation may also try to achieve the goal set by the system. Some examples of BCSSs using social support include Jaques et al. who developed a web-based pairing application in which the two paired participants need to help each other with achieving their goals like drinking more water [12]. Luhanga et al. conducted a study in which they sought to promote behavior change in losing weight and balanced diet by using social competition among group members [13].

Also, devices given to users have been studied in the environment side. For example, Fortmann et al. developed a bracelet with embedded two kinds of LEDs to show the number of drinks during the day and the time passed since last time the user drank water with color-coded from green to red [7].

2.5 Strategies Used in Existed Systems and Weaknesses

According to Matthews et al.'s research, self-monitoring, social comparison, reminder, competition, suggestion were the most used features in the system for promoting physical activity with mobile applications [14]. However, some of these strategies have weak points which may cause problems with continuity and efficiency.

Reminders are quite useful for helping users to remember tasks they need to do based on the setting. However, in Karppinen et al. study [15], it was also reported that reminders might make users depend on the reminder and harm users' memory of the tasks. Participants in Stawarz et al.'s experiment who used reminders reported the lowest automaticity scores and tended to forget more often [16]. In our view, the main reason for the different performance of reminders in these studies was frequency. In Karppinen et al.'s research, a reminder message was sent to users if they didn't complete the weekly task and second reminder message if the situation didn't change. After that, the system does not send more reminder messages. In Stawarz et al.'s experiment, participants received

reminders during the whole period asking users to input the details of their meals. Based on these studies, reminders is still a part of our design but with careful consideration of frequency.

In social support, competition is a widely used feature since it can stimulate users' motivation. However, it may also harm users' motivation if the system doesn't cover privacy and social relationship. Luhanga et al.'s system shared all the information including the failed tasks that users did which might affect the privacy and social relationship and increase the unwillingness of using the system [13]. Therefore, we should carefully consider the privacy problem when we apply social support to our design.

The self-monitoring is in many settings the most applied feature in promoting behavior change with mobile phones [14]. However, the limitation of self-monitoring is that the method for a great extent relies on the user. If users do not input or forget to input the data, then there is no data to process. Current systems often combine the self-monitoring with the reminder as Stawarz et al. did [16], which causes a vicious circle that users would hardly form a daily habit of monitoring and logging themselves, which is against the purpose of behavior change. Therefore, self-monitoring should be more active in presenting the situation of the user instead of just waiting for the user to check and input data.

A fundamental problem with the existed systems is that they are usually developed as mobile applications because users always carry their smartphones, which makes it possible for researchers and developers to collect users' data and sensing the environmental context around users. By using smartphone applications, people can reduce the cost since there is no additional cost for additional devices. However, this approach has a problem with sending triggers. The typical way in current systems for presenting information to users is using push notifications. However, users nowadays receive so many notifications from various apps which can interrupt the messages from the behavior change apps. Also, if users change their phones to silent mode, it is more difficult for them to notice the messages. Besides, according to the survey studies by West et al. [17] and Cowan et al. [18], many paid applications in App Store and Google Play lack the grounds of behavioral change theory which make their effectiveness doubtful.

Therefore, we need alternative approaches based on behavior change theory

for improving the efficiency of digital intervention and the quality of behavior change including inducing behavior change and maintaining the result.

3. Proposed BCSS Environment Design

3.1 The Intent

To design an environment for a behavior change support system, we first need to identify key behavioral patterns that foster behavioral change and maintenance and determine when and how the system should intervene. The behavior change environment here means an enclosed place where people spend a long time (e.g., a company, a university or an elder care center) equipped with smart devices for inducing the change. In Alahäivälä et al.'s research, it was reported that most of the research on health behavior change was focusing on the reinforcing outcome (R/B) and much less focused on forming (F/B) or altering a behavior (A/B) [19]. Due to individual differences, especially the differences in personal experiences, it is reasonable that altering or forming a behavior is much harder than reinforcing an existing one. However, in our research, altering or forming a behavior like promoting people to quit smoking or starting muscle training are also goals we want to achieve. Our design is focusing on the common issues that users meet with during in their daily lives in this kind of environment and trying to deal with addressing attitude, behavior change and an act of complying [1]. The common issues include improving health condition (e.g., diet, sleep, exercise, stress, drink water) and the environment (e.g., save energy, keep the environment clean). We believe that by using this system, many kinds of behaviors in daily life, such as replacing the water in the hot pot for other people and doing a health checkup while waiting for the coffee, among many others, can be induced.

3.2 The Event

To determine the user context and use context, we need to identify users and understand users' status. In our design, by observing the Bluetooth signal emitted from the BLE beacon or the application carried by users, the system can identify the target user. To understand users' status, we collect users' needs, goals, past performance, and the current process with the cooperation of smart devices such as smart watches, interactive signages.

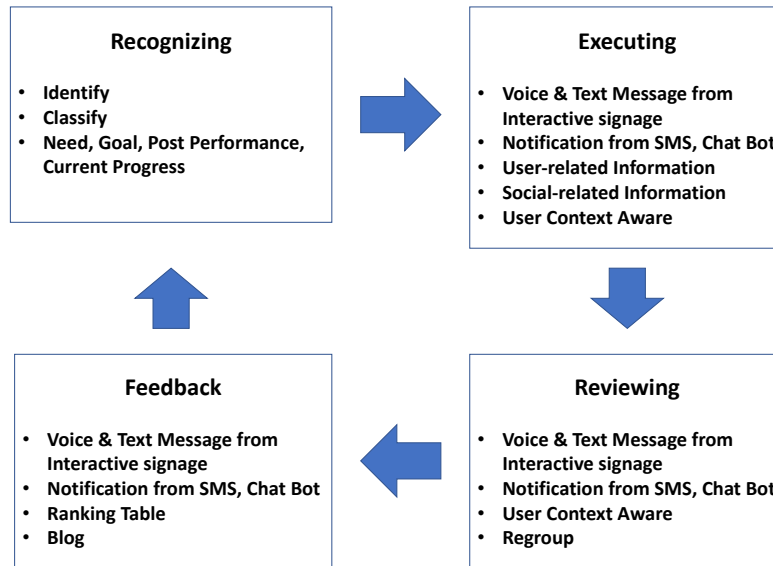


Figure 1. Form of Proposed Behavior Change Environment

3.3 The Strategy

As the route of sending the message, instead of push notification, in this design, we send voice and text message through the interactive signage to stimulate a user’s visual and auditory senses. The voice message is expected not only to arouse user’s curiosity but also to get trust from a user [20]. As the content of the message, in this design, we send the message containing the user-related information. The user-related information is selected by the personal data such as age, sex, and height. We expect that this information can attract the user more than non-related information. Also, to achieve voluntary participation, our system is deployed in the users’ life action line (the moving route of users’ daily life) and stimulate their senses continuously.

3.4 Configuration of Proposed System

In this subsection, we describe the form of our design. To achieve the goal of forming, altering or reinforcing users’ attitude and behavior, we designed a behavior change environment consisting of 4 stages: recognizing, executing, reviewing,

feedback, as shown in Fig.1.

The recognizing stage is mainly for identifying and classifying the user. We identify the target user by the signal of the carried BLE beacon and the application in their smartphones. To provide appropriate information to the user, we collect users' needs, goals, past performance, and current progress in this stage through the inquiry from the interactive signage. After collecting these data, the system classifies users and divides them into different groups.

The executing stage is the place where we try to induce a behavior change. In this stage, the interactive signage sends a voice and text message containing user-related information and the social-related information to the target user. If the user doesn't notice the message, another notification is sent by the chatbot to the user. The user-related information means the content containing the user's data like name, gender, age, and weight. The social-related information means the content containing other user's information like their needs, goals, and progress. The content presented to the user is adjusted depending on the group of the user. For example, for the people who have high efficacy, the content focuses more on keeping the motivation of the user. For the low-efficacy people, the content focuses more on improving motivation. To adjust the timing of presenting the information, we collect the user's bio-data (e.g., heart rate, number of steps) and location information.

In the reviewing stage, we record the user's reaction toward the information from the system. For the behavior related to movement and location, we estimate the user's reaction through the users' data, whereas other behavioral patterns, we confirm the result through the response to the inquiry and notifications of the user. We regroup users again based on the result.

The feedback stage is for keeping and improving users' motivation. If the user responded to the message from the signage, the signage sends a voice or text message as feedback. Also, the ranking table and a chart of the progress of the whole group is a part of the feedback. A blog (or report) about the progress of an individual or a group is sent to the social media periodically. The content of feedback depends on the group of the user.

Table 2. The strategies applied to the design

Primary Task	Dialogue Support	Social Support
<ul style="list-style-type: none"> • Reduction 	<ul style="list-style-type: none"> • Praise 	<ul style="list-style-type: none"> • Comparison
<ul style="list-style-type: none"> • Self-monitoring 	<ul style="list-style-type: none"> • Suggestion • Reminder 	<ul style="list-style-type: none"> • Facilitation • Competition

3.5 Software Feature Used in The Proposed Design

Table 2 lists the features we apply to our design among 28 features listed in the BCSS theory [1, 9].

Reduction means to reduce a complex behavior into simple tasks which helps users perform the target behavior, and it may increase the benefit/cost ratio of a behavior [1, 9]. In our design, all the behavior patterns are broken into smaller tasks and guide users to achieve the small tasks step by step. Another effort for the reduction in this design is that we let users respond to the inquiry by pushing a single button and only a few cases need users to input text.

Self-monitoring is widely used in the current systems because it can show the progress of users and the distance to their goals. In this design, we provide a way for the users to check their progress by themselves. Meanwhile, we also present their progress actively by the chatbot and signage so the low-motivation people can also be aware of their situation.

In this design, we apply both voice and text praise to our feedback part. The tone and the content of the voice message change based on the result of reviewing.

The excessive use of reminders can harm users' memory to the tasks. Therefore, in this design, the reminder is kept at a low level. Suggestion to some extent have a similar role as reminders, but it persuades people in softer ways. However, it is still unclear that how would the suggestion affect the user's cognition. Investigating the effect of suggestion is a part of this research.

System users have a greater motivation to perform the target behavior if they can compare their performance with the performance of other users, discern via the system that others are performing the behavior along with them or able to compete with other users [1, 9]. We consider the environment as a small society,

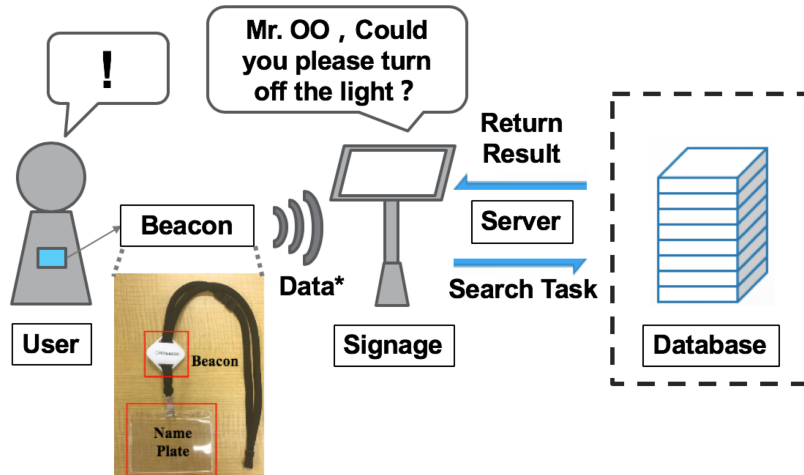
and we apply comparison, facilitation, competition to our design. We present a ranking table listing the progress of the members who have the same need or goal to the user so that they can be aware of the situation of the others and compare the performance. Moreover, we also present other users' goals to the user who doesn't have the same goal. For example, "20 members are trying to achieve walking 10000 steps a day!". To achieve the competition function, in our design, the chatbot writes a periodical blog/report about the user who does the best performance. For example, "Weekly star, the man who walked most" and "Monthly star, the man who saved the most energy".

According to the theory of goal setting, people with high self-efficacy set higher goals and have higher performance than people with low self-efficacy [8]. Therefore, it's necessary to distinguish users' type and deal with them based on the type. In this design, we divide users into several groups based on their needs, goals, past performance and current progress. Also, people who have high self-efficacy can set their own goals while the low self-efficacy people need to select the goals provided by the system.

Gamification may be sufficient for improving user motivation, and indeed it overlaps with our design with regards to multiple strategies such as social competition and comparison. However, because gamification combines a set of persuasion strategies with a playful user interface, in the case of achieved behavior change it still would be difficult to differentiate whether it resulted from playfulness or the persuasion. Therefore, we decided not to import any more gamification elements into our design for this time.

3.6 Interactive Signage System

Due to the limitations of push notification, we design an interactive signage system with an active talk function, and decide to send voice and text message through the interactive signage system to stimulate users' visual and auditory senses. Since this system does not exist in the previous study, we believe it is necessary to investigate users' reaction to the signage system, voice message function, and the personal data collection before we apply all the points in our proposed design. Therefore, we develop a prototype of the interactive signage system without any software feature and the cooperation of other smart devices.



***Data contains information of UUID, Major, Minor**

Figure 2. System Configuration of Proposed Interactive Signage System

Fig.2 shows the configuration of the interactive signage system. This system consists of a Bluetooth Low Energy (BLE) beacon worn by each user to identify themselves, a digital signage to receive beacon signals and present information to users, a server to store information of users, and tasks and records of users' reaction. The beacon is attached to the neck strap with a student ID card worn daily by the users. Compared to the existing signage system that uses a camera for user identification, the beacon-based identification system is robust against the angle and distance between a user and signage. The digital signage is equipped with a touch panel so users can respond with touch input.

The digital signage continually monitors surrounding beacon signals. Every time a user approaches and the wireless signal sent from the beacon is detected, the system performs the following operations.

3.6.1 Recognizing

First, digital signage obtains the Received Signal Strength Indicator (RSSI) from beacons and compares it with the preset threshold value. When the RSSI exceeds the preset threshold value, digital signage recognizes that a user is approaching. Then it requests the task appropriate for the user to the server. The request

message contains the information of the received beacon signal (UUID, Major, Minor) and ID of digital signage. Since RSSI varies depending on the structure of a building and the location of digital signage, the threshold value is adjusted empirically through the experiment.

3.6.2 Executing

The server searches for available and proper tasks for the user based on four factors:

- The time of day: In our system, available tasks change depending on the time of day. For example, the tasks for checking the quality of sleep and the state of breakfast is appropriate only in the morning. On the other hand, the tasks for checking the state of dinner is available only after the evening.
- The attributes of a user: All the users have their user-related tasks. For example, if the user is a Japanese, then the task is presented in Japanese. Otherwise, the task is presented in English.
- The status of the task: The same task is not shown to the same user until the cooldown time expires, so as not to impose a burden on the user.
- Location: We install some digital signage at the corridor and public spaces and set 15 minutes cooldown time to prevent the system from asking frequent questions to the user who stays in the same location for a long time.

After selecting available tasks based on the above four factors, the server sends the selected task back to the digital signage. Digital signage presents the task obtained from the server to the user.

3.6.3 Reviewing

There are two ways for the user to respond to the task. The first way is a button selection, the simplest way. Simplifying the way of answering is important to prevent users from feeling bothersome, so digital signage shows the choices of the answer by buttons. The second way is a text input. Especially for collecting personal information such as age, height, weight, etc. at the initial stage, a text

input is suitable. Reject button also appears on the screen for some personal tasks, providing a right to skip the inappropriate task explicitly.

3.6.4 Feedback

Digital signage shows a text message, “Thank you”, as a feedback and automatically goes back to the initial screen after getting a response from the user. Also, we set a timeout to handle the situation that a user cannot reply or do not notice the voice message. In such a case, the result is recorded as “ignored”. If the user does not respond to a task, the signage goes back to the initial screen after a certain time period. A result (including ignoring and rejecting) will be uploaded to the server and stored in the database.

4. Study 1: Users' Reaction to The Interactive Signage

We evaluate the performance of our interactive signage system comprehensively and investigate the effects of the interactive-signage-based stimulation because our system does not base on the pre-studied theories. There are the following three points which we need to confirm.

- First, the stimulation in our system is sending utterance to passing user, so it is necessary to check whether users respond to the utterance from the interactive signage.
- Second, to present the user-related information, it is important to collect personal data (e.g., gender, height, weight) and we prepared several inquiries for users to see whether the system can collect personal data from a user.
- Third, besides sending utterance, the stimulation also contains deploying our system in users' daily action line to send triggers continuously, and it is necessary to check whether the stimulation can promote a behavior change or not.

To investigate the effects of interactive-signage-based stimulation, we designed a survey experiment with caring about the bias because the experimenter and participants are the members of the same laboratory. The experiment was planned to be held in two weeks (one week with bias and one week without bias). However, the actual experimentation period was extended to 3 weeks because there was a long holiday period in between. The first week started from April 24th and ended on April 29th, 6 days in total. The next two weeks started from April 30th and end on May 11th, 12 days in total. During the first week, we asked participants to respond to the utterance from interactive signage whenever they noticed the voice message, including pushing a reject button. During the next two weeks, participants were not asked to respond to the task definitely to eliminate the bias. The reason for this experiment scenario is to compare the difference of participants' reactions in an ideal condition (forced to respond) and a real condition (free to respond).

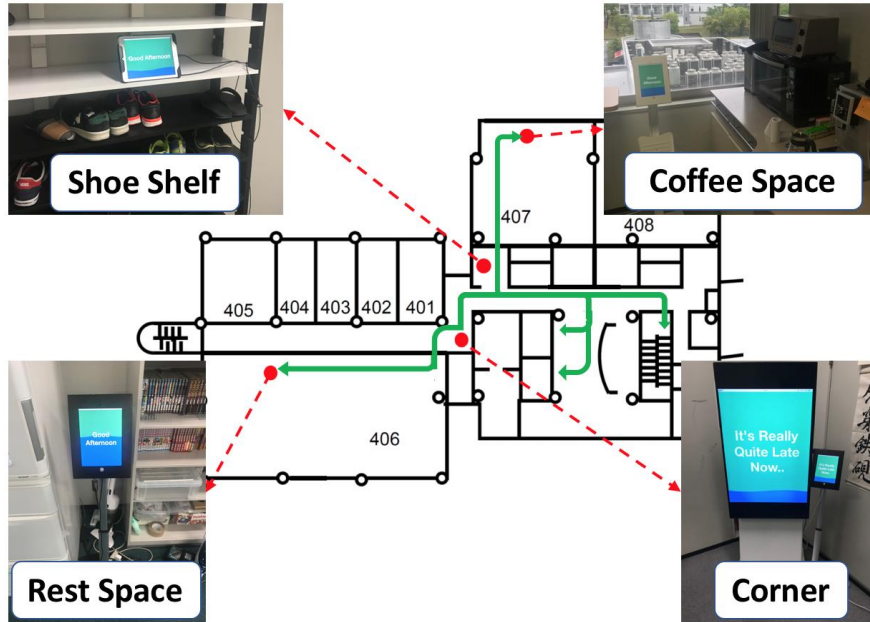


Figure 3. Location of Interactive Signage

4.1 Environmental Setup

We deployed four interactive signages at four places in our laboratory (the 4th floor of the NAIST Building A) as shown in Fig. 3.

To check the effect of setting our system in users' daily action line (a part of stimulation), we deployed the interactive signages at four positions in the route through which lab members usually pass in their daily life. The first location was a rest space in student room (A406) where drinks and snacks are available, along with two beds and a shelf of comics. A member who wants to take a break or pick some drinks and snacks always come there. To collect the data of user's daily life pattern, we decided to set interactive signage here. Besides, a weight scale was also put there for promoting members to measure their weight. It was a task related to a behavioral change. The second location was a corner of the corridor leading to the laboratory which has space for large signage. The third place was a shelf of shoes because lab members stop at this place for sure when they wear or take off shoes. We believe that this position is the most suitable

for contacting a user. Besides, it is the best location to confirm the state of the seminar room (A407), which is next to the shelf of shoes. Similarly to a weight scale, the task related to a behavioral change is posted to a user at this location. For example, digital signage asked the usage of A407 or the status of room light in A407, and promote the next behavior for saving energy. If the user turned off the light in case no one was in A407, we could say that digital signage succeeds to change the user’s behavior. The last place was a coffee space. This coffee space has an oven, a microwave, a coffee maker and a hot water pot. So, the members who want to drink coffee or heat food up often come here and stay for several minutes. We think that this short period is an excellent chance to interact with a user and promote a different behavior such as checking the remaining amount of consumables.

4.2 User Setup

15 participants participated in our experiment. We asked all the participants to carry the name tag with a BLE beacon. The transmission frequency of the beacon signal is 1 Hz. Also, we registered the name, language (English or Japanese) and ID of beacon assigned to each participant on the server.

4.3 Scenario

Table 3-4 show the list of the scenarios we prepared for this experiment. Since scenario consists the content of voice and text message and the options of responding(answer button, reject button, and text input field) presented to participants, it is the core part of the stimulation in our system. Considering that we want to explore whether our system can collect personal data from participants and promote behavior change or not, we prepared 5 different sets of scenario (Personal Task, Check Task, Personal+ Task, Check+ Task, and Action Task) in advance.

Personal Task is a task with the aim to collect personal data from the user. Before inducing a behavior change, it is essential to recognize the user’s life patterns. Therefore, besides the inquiries of the basic personal information (gender, age, nationality, height, and weight), we also prepared the inquiries that collect users’ diet, sleep, and mental status. Besides, for each signage deployed in the

Table 3. The List of Tasks Prepared (Part.1)

Task Category	Content	Time Cost	Labor Cost	Difficulty (0~3)
Personal	Should I call you Sir or Madam?	Instant	Push Button	0
Personal	Could you please tell me your age?	Few Seconds	Input Text	1
Personal	What country are you from?	Few Seconds	Input Text	1
Personal	Could you please tell me how tall are you?	Few Seconds	Input Text	1
Personal	Could you please tell me your weight?	Few Seconds	Input Text	1
Personal	Are you feeling stressful now?	Instant	Push Button	0
Personal	Have you eaten your breakfast yet?	Instant	Push Button	0
Personal	Have you eaten your lunch yet?	Instant	Push Button	0
Personal	Have you eaten your dinner yet?	Instant	Push Button	0
Personal	Did you sleep well last night?	Instant	Push Button	0
Personal	The reason you come here is? (*For Rest Space)	Instant	Push Button	0
Personal	Where are you going? (*For Corner of Corridor)	Instant	Push Button	0
Personal	You come here for? (* For Coffee Spcae)	Instant	Push Button	0

Table 4. The List of Tasks Prepared (Part.2)

Task Category	Content	Time Cost	Labor Cost	Difficulty (0~3)
Personal+	Have you check your weight recently?	Instant	Push Button	0
Action	Do you want to use the weight scale to check your weight?	Few Seconds	Push Button & Use Weight Scale	1
Check	Is Mizumoto-San in Lab now?	Few Seconds	Check & Push Button	1
Check	Are Secretaries in their Office now?	Few Seconds	Check & Push Button	1
Check	Does the water pod have enough water?	Few Seconds	Check & Push Button	1
Check	Does the coffee maker have enough water?	Few Seconds	Check & Push Button	1
Check	Are there many people in lab now?	Few Seconds	Check & Push Button	1
Check+	Is there anyone in A407 now?	Few Seconds	Go to A407 & Check	1
Action	Could you please turn off the light if it's on?	Few Seconds	Go to A407 & Turn Off the Light	1

rest space, corner of the corridor, and coffee space, we set 1 inquiry checking the reason why the user goes there to recognize users' life patterns. In order not to cause misunderstanding, in Table 3, we add comments in parentheses for these 3 inquiries and the contents presented to the user during the experiment doesn't contain the comment part.

Personal+ Task is a particular Personal Task that combined with an Action Task and system judges whether presents the Action Task to the user or not based on users' response to the Personal+ Task. In this experiment, we prepared a Personal+ Task that asks whether the user has checked his or her weight recently. If not, the system presents the Action Task that encourages the user to use the weight scale near the signage to measure their weight.

The ultimate goal of Check Task is leading users to finish the tasks that improve the environment like cleaning the office, cleaning the waste from the coffee maker, or replacing the water in the humidifier. However, due to the high cost of time and labor, it is hard to realize this goal immediately. Therefore, we set several scenarios which have a lower cost of time and labor to investigate users' reaction to this kind of task. We believe the result can guide our future work.

Check+ Task is a particular Check Task that combined with an Action Task. With the same as Personal+ Task, the system judges whether presents the Action Task to the user based on the user's response to the Check+ Task. We prepared a Check+ Task letting users check if someone is using Room A407. If nobody is using the room, the system presents the Action Task that encourages users to close the light of A407 for saving energy.

Users can respond to the task through a touchscreen. The number of tasks in those task sets was 13 (Personal), 1 (Personal+), 5 (Check), 1 (Check+), 2 (Action) respectively. The total number of tasks was 22. Both Japanese and English descriptions were prepared for all the tasks so that the international students who cannot understand Japanese also participated.

Table 3-4 also show the difficulty of each task. The standard for measuring the difficulty is basing on the cost of time and labor of finishing the task. We set four levels to evaluate the difficulty of each task. Level 0 means users can finish the task immediately without any difficulty (e.g., Push a button on the screen).

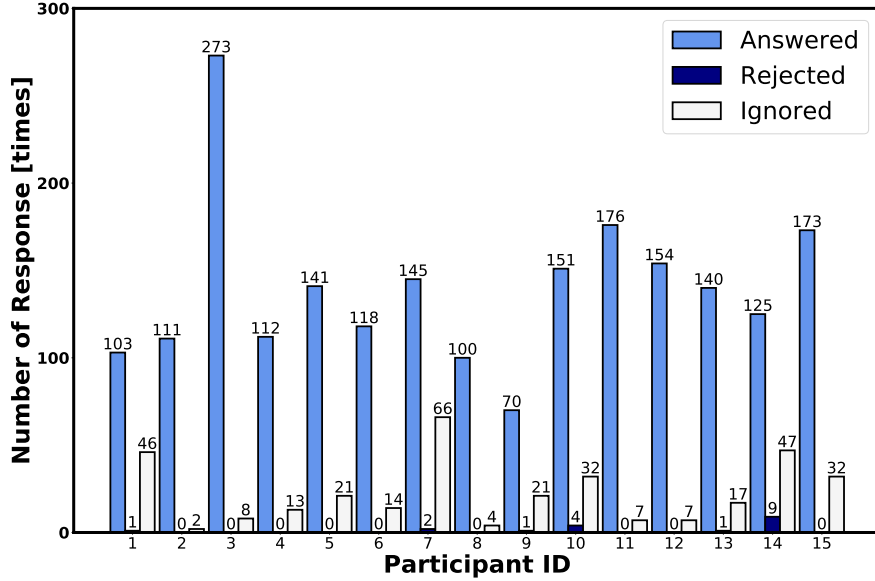


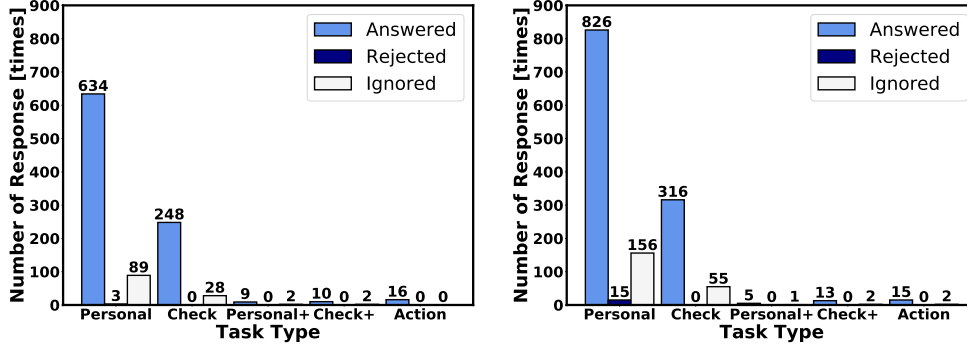
Figure 4. Response Results of 15 Participants

Level 1 means users need to spend a little bit time and labor to finish the task (e.g., Check the amount of the water left in the hot pot first, then push button to respond). Level 2 means users need to spend a long time and more labor to finish the task (e.g., clean the waster from the coffee maker, replacing the water in the hot pot). Level 3 means users need to move a long distance and use more power to finish the task (e.g., clean the office room, collect the garbage and throw it to the designated location). However, in this experiment, we didn't prepare the task of Level 2 and Level 3.

After the 3-week experiment, we asked all participants to answer a questionnaire about the timing of inquiry, the impression of each task and their opinion of voice message function.

4.4 Result and Discussion

During the experiment, we collected a total of 2447 responses, of which 18 responses were rejection, and 337 responses were ignorance. Fig.4 shows the ratio of response types (Answered, Rejected, Ignored) of 15 participants. The aver-



(First Week)

(Second-Third Weeks)

Figure 5. Response Result of Each Task Type

Table 5. The breakdown of response of action tasks

Contents	Result	Times
If the light in A407 is on, could you please turn it off?	No, I'm kind of busy now	1
	It's off now	10
	Someone is using A407 now!	1
Do you want to use the weight scale to check your weight?	Ignore	2
	No,thanks	2
	Sure,let's see	1

age number of responses from each participant was 61.1 times during the first week (forced to respond) and 78.3 times during the next two weeks (free to respond). The average response rate during the next two week was 84.49% and the response rate of each task type was 84.35% (Personal Task), 83.33% (Personal+ Task), 85.18% (Check Task), 86.67% (Check+ Task), 88.24% (Action Task), indicating that people responded to the inquiry from interactive signage with high probability.

Result and Discussion of Each Task Type

According to Fig.5, the first thing we can know is the percentage of Personal tasks is much higher than the other tasks. It is because we prepared 13 kinds of Personal Tasks in this experiment, which is much more than the other task

Table 6. The Breakdown of Response of Check Tasks

Contents	Result	Times	Response Rate
Are secretaries in their office now?	Ignore	16	86.55%
	Yes, they are	75	
	No, they aren't	28	
Is Mizumoto-San in Lab now?	Ignore	9	59.09%
	Yes, he is	9	
	No, he isn't	4	
Does the coffee maker have enough water?	Ignore	4	80.95%
	It's lower than 30%	4	
	Yes, like 30%~80%	7	
	Yes, it's over 80%	6	
Does the water pot still have enough water?	Ignore	3	87.5%
	It's lower than 30%	5	
	Yes, like 30%~80%	9	
	Yes, it's over 80%	7	
How many people are there in lab now?	Ignore	24	87.56%
	Over 15 people	72	
	About 10 people	52	
	About 5 people	34	
	Other	4	

type (Personal+ Task:1, Check Task: 5, Check+ Task: 1, Action Task: 2) and participants can answer 9 of the Personal Task easily by pushing button. The reason for the low number of Personal+ Task, Check+ Task, and Action Task is the system only present these tasks when a participant goes to a fixed location during a fixed time of a day. For example, the Check+ Task for checking the status of the light in Room A407 can only appear in the interactive signage set on the shoe shelf after 8 pm.

The response rate of Personal Task was 87.74% with bias and 84.35% without bias. And the response rate of Personal+ Task was 81.82% with bias and 83.33% without bias, indicating that the interactive signage can collect personal data without bias to a certain degree.

Table 5 shows the breakdown of responses to action tasks during the next two weeks. Against the task of checking the light status in A407, the participants answered 12 times without ignorance. However, we could not confirm that the light was turned off or not by stimulation from our digital signage because we didn't include any sensing system for it. Meanwhile, the task of persuading a user to use a weight scale got the response of 1 answered, 2 rejected, 2 ignored, which means that our digital signage succeeded to change behavior at least one time.

Table 6 shows the breakdown of Check Tasks. To respond to these tasks checking members' status, participants need to go the related place like Secretary Room and Student Room. And for the task that checks equipment, participants need to look closely and confirm the status like the amount of the water left in the hot pot. These tasks cost the user a little bit of labor and time, so the difficulty of these tasks is Level 1. The result shows that except the task "Is Mizumoto-San in Lab now?", the response rate of Check Task was very high, indicating that interactive signage can promote low time and labor costs behavior effectively. The exception task only appears when participants go to the rest space, therefore the system presented tasks to the participants who was sleeping on the sofa in the rest space can be considered as the reason for the low response rate.

Result and Discussion of Each Time of Day

Fig.6 shows the response result of each time of a day during the first week and the next two weeks, respectively. The x-axis stands for the time of a day, and the y-axis stands for the number of responses. The graphs clearly show that the rate of rejection and ignorance raised in the latter two weeks of the experiment. The graphs also show that the highest rate of answered was achieved between 8:00 am and 10:00 am, and the lowest was achieved between 15:00 pm and 16:00 pm. The first reason for this is that the participants were getting busy in the afternoon and had no time to respond to the task. The second reason is that participants may have got tired of the task since they had already answered many tasks in the morning.

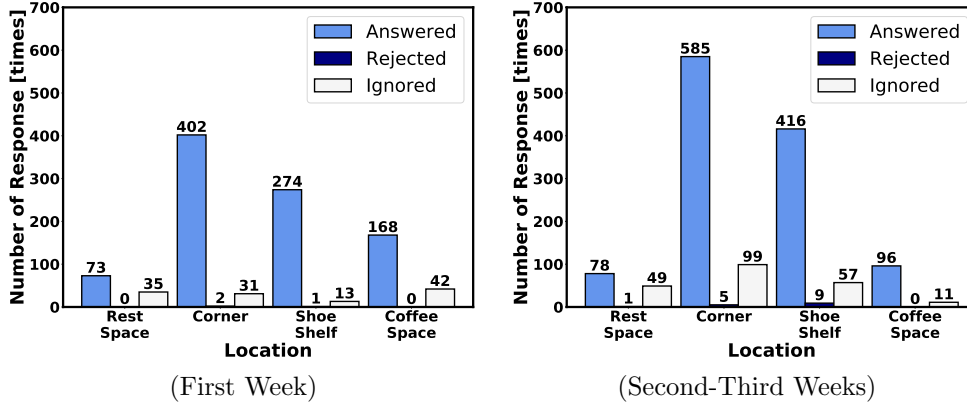


Figure 7. Response Result of Each Location of Signage

To induce behavior change effectively, we believe it is necessary to recognize users' life patterns which means we need to collect a lot of personal data from users. Moreover, the privacy issue is always accompanying with the development of the BCSS. In this experiment, we tried to collect low sensitive personal data (basic personal data and the purpose of movement) from participants, and the result of the questionnaire showed that most of them were willing to provide these low sensitive personal information.

Mental health is always a big part of the quality of life, and it is necessary to check members' mental status. In this experiment, we asked participants about their mental health directly. However, due to the stiffness of the content, participants reported that they even felt stressful when they heard the task. Therefore, a content which full of humanity is needed.

In this experiment, we tried to induce the behavior change that costs a little bit of labor and time. However, we didn't prepare any feedback but only a text message, "Thank You", for finishing the Check Task, which can be considered as the reason for 6 participants reported that they didn't want to check the statement of members or equipment. We need more effort on the feedback in improving users' motivation,

Lastly, we asked participants what do they think about the voice message function and let them free to answer. 9 participants gave a high score to the function and said it was fascinating. Moreover, 4 participants reported that

the voice message could remind them to respond. Based on these feedback from participants and the high response rate (84.49% without bias) to the inquiries, we confirmed that the voice message function could raise users' attention and interest with a high probability. Besides, we also got a report that he felt stressed when he always hears the same voice message. Therefore, the diversification of content is needed.

Based on the above results, we could say that the voice message function could raise users' attention with a high probability. Also, we found that interactive signage can effectively induce low time and labor costs behavior change like pushing a button and checking statement of members and equipment. We also found that deploying signage in the route that users pass daily is useful for raising the rate of answering. Besides, the results also confirmed that the interactive signage could collect personal data effectively.

Table 7. Breakdown of Questionnaire

Question	Option	Result
How did you feel when you heard the question about your personal data (Age, Weight, Height, Country, Gender)	It's OK to tell my personal information to the system	10
	I don't want to let the system know about my personal information	2
How did you feel when you heard the question for checking the purpose of your movement	It's OK to tell the system where I'm going or what I'm going to do.	13
	I feel uncomfortable when someone ask me this kind of question	1
How did you feel when you heard the question for checking the statement of members or equipment	It's OK for me to check the statement out	7
	It's troublesome and I don't want to check the statement of members or equipment	6
	It's troublesome but it's good to know how many water left	1
How did you feel when you heard the question about your mental state	I think it's good that someone cares about my mental state	6
	I feel stressed when I heard this task	8

5. Study 2: Users’ Response Time and Reaction to The Voice Feedback

5.1 Environmental Setup

We conducted an additional experiment in addition to the previous experiment described above. Since the response time (the time passed from showing task until users respond) is a part of users’ reactions and the effect of stimulation, we believe that the evaluation of the response time is necessary. To collect response time, we updated our interactive signage system and did an additional experiment with the same participants (except for 1 missing participant) for investigating their reaction to the new voice message feedback function and collecting data of response time. The period of the additional experiment was 1 week. Before the additional experiment, the rule of presenting the Check Task was independent for each user which means the response from one user won’t affect the presentation of the same task to other users. However, some participants reported that these tasks become a burden for them. Therefore, in this experiment, we changed the rule of presenting the Check Task from “Independent for each user” to “Once there is someone respond the task, then the same task won’t be presented to other users again until the cooldown is finished” to reduce the burden of users. In the additional experiment, we set several patterns of voice feedback for participants and it changes depends on the amount of the tasks that the participant responded. For example, at first, they may only hear “Thank You”. After they respond to some tasks, they can hear “Mr.(users’ name), thank you very much for responding”. After the experiment, we asked all participants to answer the questionnaire about their feelings to the newly added voice feedback.

5.2 User Setup

We invited the participants who joined the previous experiment, and 14 of them joined in our additional experiment. As the same with the former experiment, we asked all the participants to carry the name tag with a BLE beacon during the experiment period. However, due to one participant went for a business trip and quit our experiment, there were only 13 participants finished the experiment.

5.3 Scenario

Before the additional experiment, the rule of presenting the Check Task was independent for each user which means the response from one user won't affect the presentation of the same task to other users. However, some participants reported that these tasks become a burden for them. Therefore, in this experiment, we changed the rule of presenting the Check Task from "Independent for each user" to "Once there is someone respond the task, then the same task won't be presented to other users again until the cooldown is finished" to reduce the burden of users.

5.4 Response Time Record Function

Since the response time (the time passed from showing task until users respond) is a part of users' reactions and the effect of stimulation, we believe that the evaluation of the response time is necessary. To collect response time, we updated our interactive signage system by adding the response time record function.

5.5 Voice Message Feedback Function

In the additional experiment, we set several patterns of voice feedback for participants and it changes depends on the amount of the tasks that the participant responded. For example, at first, they may only hear "Thank You". After they respond to some tasks, they can hear "Mr.(users' name), thank you very much for responding". After the experiment, we asked all participants to answer the questionnaire about their feelings to the newly added voice feedback.

5.6 Result and Discussion

During the additional experiment, we collected a total of 753 responses, of which 10 responses were rejection, and 158 responses were ignorance. Fig.8 shows the ratio of response types (Answered, Rejected, Ignored) of 14 participants. However, 1 participant exit for a business trip and only 13 people finished the additional experiment. The average number of responses for each participant was 45.8 which is close to the average number of responses in the 3-week experiment (46.5 times per week). The average response rate in the additional experiment was 79.01%.

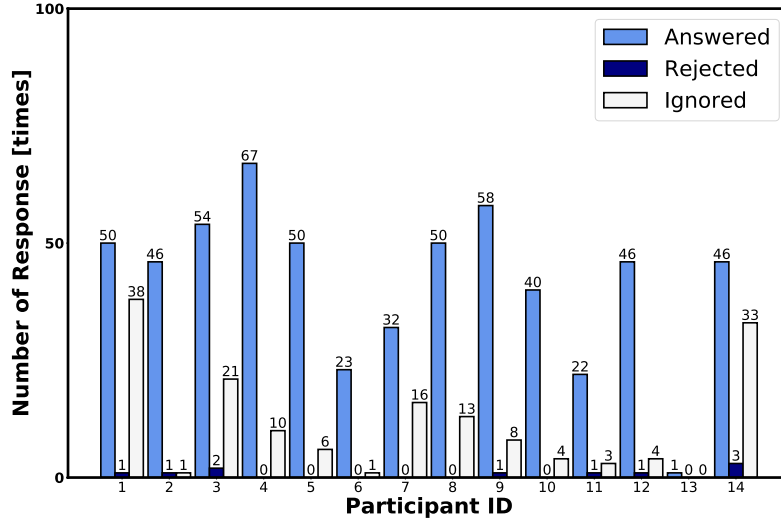


Figure 8. Response Results of 14 Participants

Although it is lower than the former experiment, we can still say that people respond to the inquiry from the interactive signage with high probability.

Result and Discussion of Each Task Type

Fig.9 shows the number of responses for each task type during the additional experiment. The x-axis shows the type of task, and the y-axis shows the number of responses. There are 3 types of response: Answered, Rejected, Ignored. The response rate of each task type was 78.85% (Personal Task), 83.33% (Personal+ Task), 81.30% (Check Task), 100% (Check+ Task), 54.55% (Action Task) respectively. Because of the serious conditions and few patterns, Personal+ Task, Check+ Task, and Action Task were triggered for only a few times as the same as in the former experiment. Moreover, after we updated our system, the condition of Check Task has been changed to if system received a response of the task, then the system does not present the task to other users until it finishes the cooldown. Therefore, the percentage of Check Task was lower than in the former experiment. However, the response rate of Check Task was still high enough which

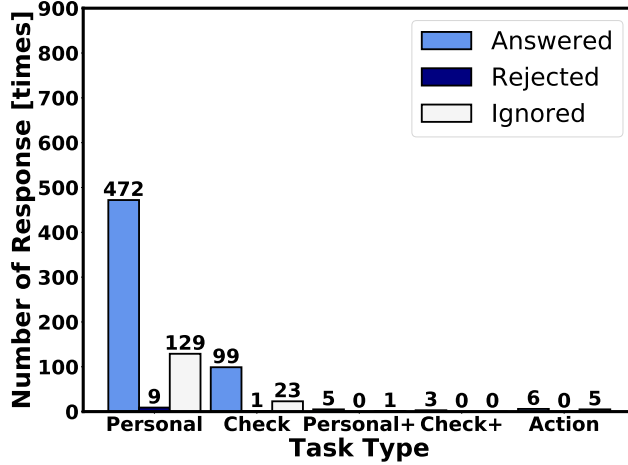


Figure 9. Response Results of Each Task Type

Table 8. The response rate of each task type in former and additional experiment

Type	First Week	Second Third Week	Additional
Personal	87.74%	84.35%	78.85%
Personal+	81.82%	83.33%	83.33%
Check	89.86%	85.18%	81.30%
Check+	83.33%	86.67%	100%
Action	100%	88.24%	54.55%

indicates the interactive signage can promote behavior change with low time and labor costs effectively. The Action Tasks triggered during the period of this experiment were all the Action Tasks combined with Personal+ Task which only appears when users are near to rest space. However, due to the system cannot distinguish whether the user is resting or working, it might present the Action Task to the user who was sleeping, which caused the low response rate of Action Task. Table 8 shows the response rate of each task type in former and additional experiment.

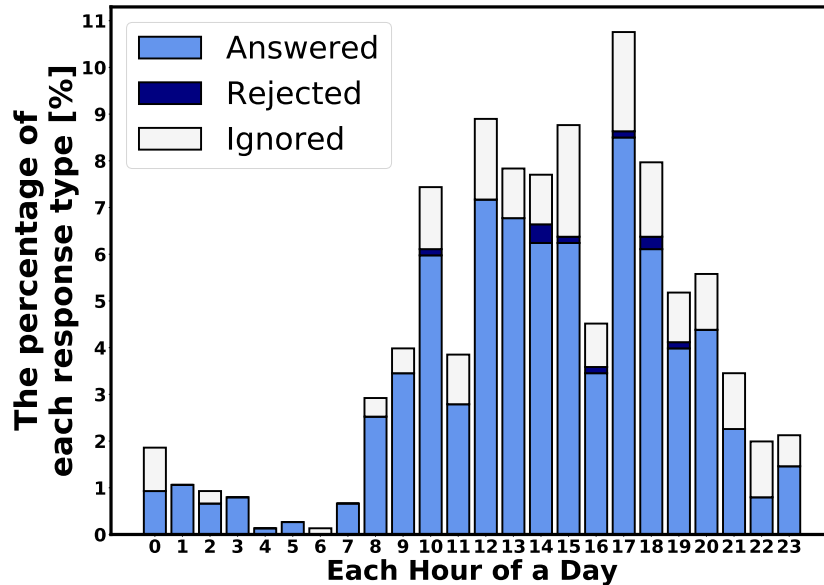


Figure 10. Response Results of Each Task Type

Result and Discussion of Each Time of a Day

Fig.10 shows the response result of each time of a day in the additional experiment. The x-axis stands for the time of a day, and the y-axis stands for the number of responses. The graph shows that the rate of rejection and ignorance became higher than in the 3-week experiment. The graph also shows that the highest rate of answered was achieved between 8:00 am and 10:00 am, and the lowest was achieved between 15:00 pm and 18:00 pm, which is close to the result we got before.

Result and Discussion of Each Location

Fig.11 shows the number of responses for each location of interactive signage in the additional experiment. The x-axis stands for each location, and the y-axis stands for the number of responses. The rate of ignorance of the signage deployed in rest space was 41.53%, which is higher than before. The signage on the shoe

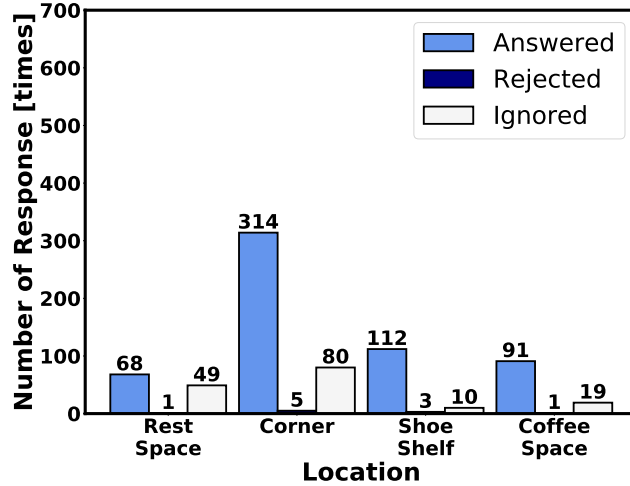


Figure 11. Response Results of Each Task Type

Table 9. The response rate of each location in former and additional experiment

Type	First Week	Second Third Week	Additional
Rest Space	67.59%	61.72%	58.47%
Corner	92.87%	85.63%	79.95%
Shoe Shelf	95.49%	88.17%	92.0%
Coffee	80.0%	89.72%	82.88%

shelf still got high answered rate (92%) and low ignorance rate (8%) during the additional experiment as same as before. According to the data collected from the signage deployed in coffee space, the rejection only happened for 1 time, and we are still able to say it is suitable for our purpose. Table 9 shows the response rate of each task type in former and additional experiment.

Based on the above result, the correctness of the conclusion we got from the 3-week experiment has been proved.

Result and Discussion of Response Time

Table 10 shows the result of the average response time of each task type and each location. Participants only need to push a button to respond most of the Personal

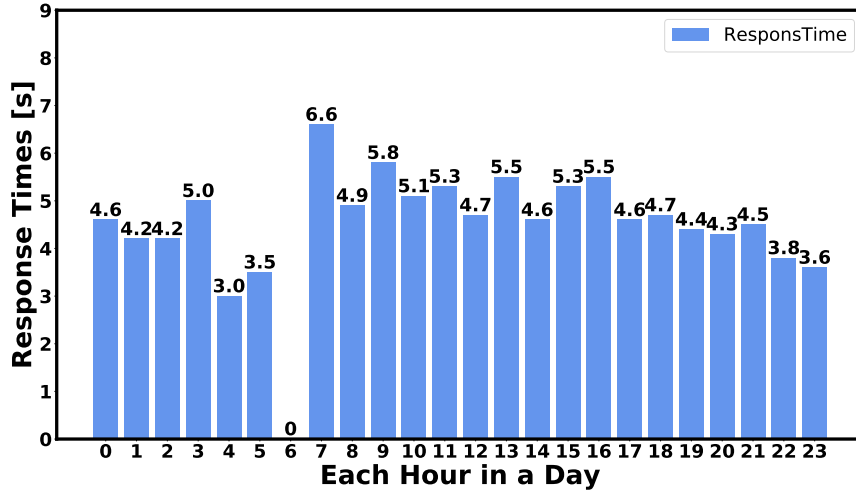


Figure 12. Result of Average Response Time in Each Time of a Day

Tasks, but the Check Task requires participants to respond after confirming the statement of members and equipment. Therefore, the response time of Personal Task is shorter than Check Task. Since the sample data of Personal+ Task, Check+ Task, Action Task are too small, we do not discuss the response time of them here. The response time of the shoe shelf was the shortest one, and the reason is whenever they wear or take off their shoes, they approach the signage and then respond to the inquiry by the way. Based on this result and the response rate in the shoe shelf, we can say setting the signage in the life action line is sufficient for collecting response. Fig.12 shows the result of the average response time of each time in a day. The average response time between 8 am to 18 pm was 5s and the average response time between 19 pm to 7 am the next day was 4.1s.

Based on the result above, we did not find a difference in response time among the type of tasks, location of signage and time zone in a day.

Table 10. Result of Average Response Time of Each Task Type, Stress Check Task, Each Location

Content	Details	Average Response Time [seconds]
Each Task Type	Personal Task	4.7
	Check Task	5.6
	Personal+ Task	6.4
	Check+ Task	4.33
	Action Task	5.0
Each Location	Rest Space	5.39
	Corner	4.84
	Shoe Shelf	3.81
	Coffee Space	5.88

Result and Discussion of Questionnaire

As a result of the questionnaire about participants' feeling to the newly added voice feedback, 9 participants reported that they felt interesting to hear the voice feedback, indicating that the voice feedback function can attract users' interest. However, there were also 3 participants who said they felt a little bit embarrassing and some patterns of the voice feedback were too long, "Thank You" would be enough. Besides, 3 participants reported that their motivation was improved after they heard the voice feedback. This result indicates that the voice feedback function can raise the interest of users and may be able to improve the motivation of users.

Effect of the Day Passed on Response Rate

The purpose of this analysis is to figure out the reason for ignorance. We assume that users' motivation for using the system decreases over time, which increases tiredness as well as ignorance to the trigger. To verify the correctness of our guess, we analyzed the task record we collected in 2 experiments. Moreover, due to the type of tasks is also a variable, we analyzed all the records by each task type to investigate the relationship between the response result of each type of task and the time passed.

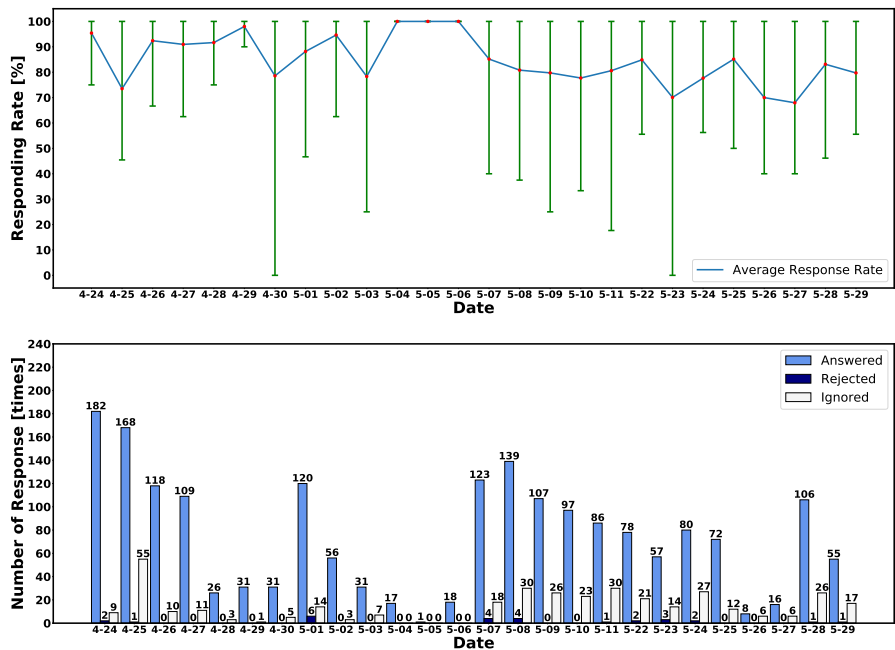


Figure 13. Response Result of Personal Task by Date

Fig.13 shows the response result of Personal Task by date. In the upper graph, the x-axis stands for the date, and the y-axis stands for the responses rate. Besides, the line stands for the average response rate in each day, and the error bars stand for the highest and lowest response rate of participants on that day. In the lower graph, the x-axis stands for the date, and the y-axis stands for the number of responses. There are three types of responses: Answered, Rejected, Ignored.

The first week started from April 24th and ended on April 29th (6 days in total), during which we asked participants to respond to the tasks whenever they noticed the voice message. Due to the bias, even if time passes, the response rate naturally does not go down. The second and third week started from April 30th and ended on May 11th (12 days in total), during which we let participants

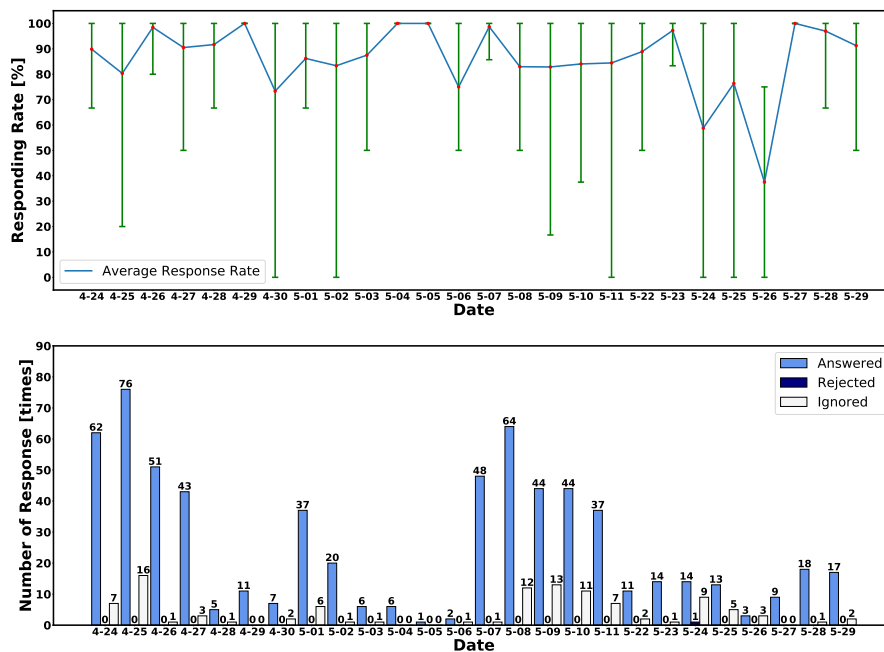


Figure 14. Response Result of Check Task by Date

free to respond to the tasks. Without the bias, the response rate goes down a little bit and become stable around 80%. Although there is a tendency that the lowest response rate in a day tends to go down, according to the lower graph, the number of ignorance has not risen. The additional experiment started from May 22nd and ended on 29th, during which we also let participants free to respond to the tasks. As time goes by, the response rate fluctuates drastically. However, according to the lower graph, this is because the number of tasks triggered in that day was small. The number of ignorance is almost the same with the previous experiment. Based on the result above, the number of ignorance of Personal Task doesn't rise even as the time passes has been proved.

Fig.14 shows the response result of the Check Task by date. In the upper graph, the x-axis stands for the date, and the y-axis stands for the responses

rate. Besides, the line stands for the average response rate in each day, and the error bars stand for the highest and lowest response rate of participants on that day. In the lower graph, the x-axis stands for the date, and the y-axis stands for the number of responses. There are three types of responses: Answered, Rejected, Ignored.

During the first week, due to the bias, even if time passes, the response rate naturally does not go down. During the second and third week without the bias, the response rate goes down a little bit and become stable around 83%. According to the lower graph, the number of ignorance has not risen. During the additional experiment, since we changed the rule of presenting Check Task, the amount of Check Task triggered decreased a lot. Although the response rate fluctuates drastically as the time goes by, according to the lower graph, this is because the number of tasks triggered in that day was small. The number of ignorance is much smaller than in the former experiment. Based on the result above, the number of ignorance of Check Task doesn't rise even as the time passes has been proved.

Since the sample data of Personal+ Task, Check+ Task, Action Task are too small and scattered, we do not discuss them here.

6. Discussion

We conducted a 3-week experiment to investigate the effect and availability of our proposed system. Through the high response rate of each task type and the result of the questionnaire, we proved that participants respond to the inquiry from the interactive signage with high probability. It is one of the results of behavior change because the signage did not exist before the experiment and hence gave the users something new to do, thereby changing their natural behavior. Moreover, according to the result of the response of Personal Task and the answers from the participants to the question about their feeling to personal data collection, we found that the interactive signage can collect low sensitive personal information from users effectively. Besides, through the result of the Check Task, we found that the interactive signage can induce the behavior change with difficulty 1 which cost a little bit time and labor. However, there are some participants say that

they don't want to do the Check Task. To improve the motivation of these people, we need more effort on the design of feedback and the content. Besides, through the questionnaire, we found that the voice message function can attract users' interest and attention.

Based on the result we got from the former experiment, we updated our system by adding voice message feedback function and response time record function. We also adjusted the rule of presenting Check Task to reduce the burden of users. After updating the system, we conducted a 1-week additional experiment with the same participants for investigating their reactions to the new system. The result of additional experiment supported the correctness of the conclusion we derived from the previous experiment. Moreover, as a result of analyzing response time, we did not find a significant difference in response time among each task type, the location of signage and timezone of a day. Besides, we assume that users' motivation for using the system decreases over time, which increases tiredness as well as ignorance to the trigger. To verify the correctness of our guess, we analyzed the task record we collected in 2 experiments. Also, due to the type of tasks is also a variable, we analyzed all the records by each task type to investigate the relationship between the response result of each type of task and the time passed. The result shows that the number of ignorance of Personal Task and Check Task does not rise even as the time passes. The rest of the task type, due to the sample data were too small and scattered, we could not get any conclusion from them.

7. Summary and Future Work

With the widespread of smart devices equipped with many sensors, people have conducted many developments and research for recognizing users' life patterns with the cooperation of smart devices. Especially in the medical field, using smart devices has been taken as the treatment of lifestyle diseases such as diabetes, obesity, hypertension which are usually caused by patients' daily habits by reviewing their lifestyle and leading them to better life patterns. This kind of system is also called as behavior change support system (BCSS). The common approach of BCSS is designing the system as a mobile application since nowadays people always carry their smartphones and there are many sensors in the smartphones which make it easy for designers and researchers to sense users and environment. These applications usually use push notification as the method for sending triggers. However, nowadays, people receive too many notifications which makes it difficult for users to notice the message from BCSS. Therefore, an alternative approach is needed.

In this thesis, we proposed an interactive signage system that can positively and actively talk to the passing users for nudging their behavioral change. Our system utilizes a wearable beacon for identifying the person and visual and auditory messages for stimulating them. We set the interactive signage system in the daily action of users. As long as the user is staying this place, our system can send triggers to the user continuously.

We conducted a 3-week experiment and an additional experiment to investigate the effect and availability of our proposed system. As the first step of promoting behavior change, we prepared 5 check tasks which cost user a little bit of time and labor to investigate users' reaction to the simple tasks. Through the result, we proved the usefulness of our interactive signage on promoting low time and labor cost behavior change. Also, we showed the effectiveness of voice message function in attracting users' attention and interest through the result of the questionnaire of the experiment. Besides, we investigated the effect of the fatigue factor by analyzing the relationship between the day passed and response rate. We found that the number of ignorance of Personal Task and Check Task does not rise even as the time passes. The rest of the task type, due to the sample data were too small and scattered, we could not get any conclusion from them.

Although we got some positive result from the experiment, we also found some limitations of our system. 7 participants reported that they did not want to do the check task after the 3-week experiment. The reason for this can be considered as the content of the task was less related to the participant and there was no attractive feedback but only text message, “Thank you!”. And there were also some people reported that they felt stressful when they heard the mental check task since the content was too strict and less humanization. They also said that they felt boring and stressful when they always hear the same content due to the patterns of the inquiry is limited.

To offset the limitation of our systems, we propose 3 approaches as the future work of this research. The first one is conducting a theory-based and attractive system. As we mentioned in Section 3.5, there are some software features picked from the BCSS theory and we are going to apply them to our system to see whether they can improve users’ motivation. Second, we are going to make humanized and flexible utterance. To achieve this, we will combine our system with other smart devices to get users’ physical data like the status of sleep, diet, heart rate, and location. Based on these data, our system can present flexible utterance like “You did not sleep well last night, what is wrong?”. The third one is making our system able to classify users automatically. It has been proved that high self-efficacy people tend to set higher goal and have better performance than the people who is low self-efficacy. Therefore, we believe it is necessary to divide people into different groups. In the future, we will let high self-efficacy people able to set goal by themselves, meanwhile, we provide several easier goals for the low self-efficacy people and lead them to improve their performance step by step.

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Appendix

A. The List of Features in Primary Task Support

Table 11. The List of Features of Primary Task Support

Feature	Content
Reduction	Divide a big task into smaller tasks to help users perform the target behavior
Tunneling	Guide users through a process or experience provides opportunities to persuade along the way
Tailoring	Tailor the information based on users' needs, interests, personality, usage context or other user-related data
Personalization	Offer personalized content or service
Self-monitoring	Provide a way for users to keep track of their own performance or status supports in achieving goals
Simulation	Provide a method for observing the link between the cause and effect with regard to users' behavior
Rehearsal	Provide a means to rehearse a behavior

B. The List of Features in Dialogue Support

Table 12. The List of Features of Dialogue Support

Feature	Content
Praise	Praise via words, images, symbols, or sounds as a way to provide users feedback information based on their behaviors
Rewards	Provide a reward to users based on their behaviors
Reminders	Remind users the tasks they have to do
Suggestion	Suggest a behavior when the user is using the system
Similarity	Imitate users in some specific way
Liking	Design an interface that users appeal to
Social role	Adopt a social role

C. The List of Features in System Credibility Support

Table 13. The List of Features of System Credibility Support

Feature	Content
Trustworthiness	Provide truthful, fair and unbiased information
Expertise	Provide information showing knowledge, experience, and competence
Surface credibility	Have competent look and feel
Real-world Feel	Provide information of the organization and/or actual people behind its content and services
Authority	Refer to people in the role of authority
Third-party Endorsements	Provide endorsements from respected sources
Verifiability	Provide means to verify the accuracy of site content via outside sources

D. The List of Features in Social Support

Table 14. The List of Features of Social Support

Feature	Content
Social learning	Provide means to observe other users who are performing their target behaviors and to see the outcomes of their behavior
Social comparison	Provide means for comparing performance with the performance with the performance of other users
Normative influence	Provide means for gathering together people who have the same goal and make them feel norms
Social facilitation	Provide means for discerning other users who are performing the behavior
Cooperation	Provide means for co-operation
Competition	Provide means for competing with other users
Recognition	Provide public recognition for users who perform their target behavior