Improvement of Health Behavior Based on Health Information Feedback

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Abstract. Recently, the average life expectancy of people has been extended, but the healthy life expectancy is not necessarily extended. In this study, in order to extend the healthy life expectancy, a framework of health information feedback was constructed to improve the health consciousness and the health behavior of the people. In this system, the push type digital signage communicates with the user's activity meter with advertising function through the BLE communication and displays customized healthcare information based on the health log analysis using the effect of gamification for each user. From the evaluation experiment, it was confirmed that the feedback of the health information led to the improvement of the health consciousness and the health behavior of the user.

Keywords: Health log data · Big data analysis · Activity meter · Digital signage · Gamification

1 Introduction

Our average life expectancy has been increasing year by year [1]. For example, Japan is one of the world's top country for longevity, and the average life expectancy of Japanese in 2016 is 81.0 years for males and 87.1 years for females. However, as for the healthy life expectancy in which people can spend their lives without nursing care, male is 72.1 years old and female is 74.8 years old [2]. There is a difference of about ten years between the healthy life expectancy and the average life expectancy. Therefore, the importance of extending the healthy life expectancy is pointed out rather than simply extending the average life expectancy. In order to extend the healthy life expectancy, it is necessary to prevent lifestyle-related diseases such as cancer, heart disease, stroke, and so on, which accounts for 60% of the cause of death [3]. Namely, it is important to improve the lifestyle itself since we are young.

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On the other hand, in recent years, various kinds of digital health devices such as activity meter and vital monitor have been developed, and the health log data can easily be recorded in daily life. For example, the bracelet type activity meter and the wrist-watch type activity meter have become very popular, and not only older people but also young people use these devices [4, 5]. As a next step, various services based on the health log data are being considered. Apple Inc. provides "healthcare" application for iPhone to store various data such as number of steps, sleep time, blood pressure, etc. as a platform to manage user's health [6]. However, these data are currently used only for the personal use. When the health log data are collected from a lot of people, they can be analyzed simultaneously as big data and the result can be used for the healthcare effectively. Namely, by using the result of big data analysis, it becomes possible to take a new method of data intensive approach for the healthcare management.

In this study, a framework of feeding back the health information that was obtained from the big data analysis of the health log data was constructed. And it was used to improve health consciousness and health behavior of the users.

2 Framework of Health Information Feedback

Figure 1 shows the framework of the health information feedback that was constructed in this study. The whole system consists of three subsystems such as health log data collection, health log data analysis, and health information feedback [7].

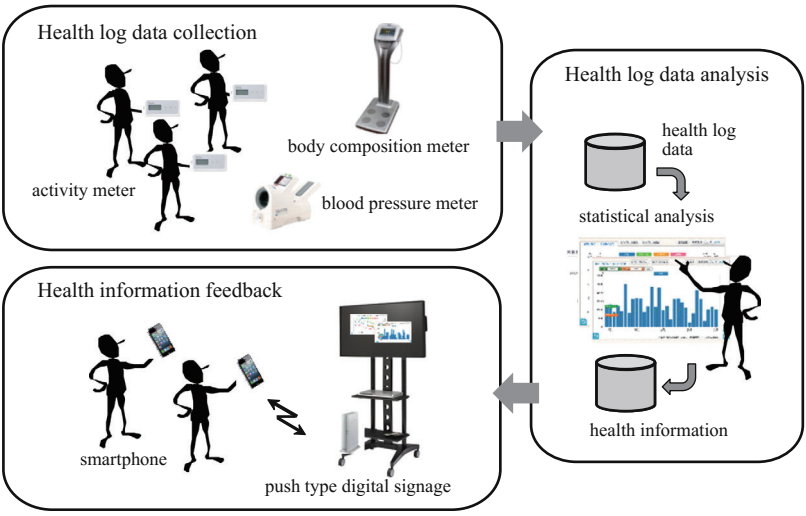

Fig. 1. Framework of health information feedback.

In the health log data collection subsystem, data measured by activity meters, body composition meters, and blood pressure meters are collected in the server through the Internet. Currently, data sent from more than 100,000 people who use Tanita's

healthcare devices are stored, and they can be used for the data analysis. The health log data analysis subsystem performs big data analysis on the offline data to derive various knowledge about the healthcare, as well as classifies and evaluates each individual's online data. In the health information feedback subsystem, the health information derived from the health log data analysis is presented to the user using the user's smartphone and the digital signage that is placed in the public space.

In recent years, as a framework to utilize the health data such as activity data or vital data, several platforms using mobile devices and servers have been constructed. For example, the platform that includes physical activity monitor [8] or the fog computing architecture [9] are used. Or the function of automated data mining [10] is introduced to utilize data. Compared with these systems, the feature of the proposed framework is that three functions such as collection, analysis, and feedback are organically integrated, and the health service is designed by using both a large amount of offline data and online data of individual users. In particular, it is expected that this framework improves the health consciousness and the health behavior of the users by integrating and functioning these subsystems with each other effectively.

3 Health Information Feedback Using Digital Signage

In this paper, we focused on the function of health information feedback based on BLE (Bluetooth Low Energy) communication between the activity meter and the push type digital signage.

3.1 Activity Meter with BLE Communication

As an activity meter, it is required not only to count and record the number of steps but also to communicate with the digital signage to feed back the personalized information. In this study, prototype of activity meter with an advertising function of BLE (Bluetooth Low Energy) communication, which was developed by modifying the product of Tanita AM-161 was used. This activity meter can originally upload measured data to the server via user's smartphone using BLE communication [11]. In this prototype, a function to advertise the BLE signal all the time was added. This advertising function was designed to output the signal at one second intervals considering that the signal can be detected before a walking user passes in front of the receiver and that the consumption of the battery is not so large. By advertising the signal constantly, ID information of the activity meter is transmitted to surrounding devices, and it can be detected by the digital signage. Figure 2 shows the prototype of the activity meter with the advertising function of BLE.

Fig. 2. Prototype of activity meter based on AM-161.

3.2 Analysis of Cumulative Number of Steps

Once the health log data are collected from a large number of users, it is expected to find various knowledge about the relationship between health and behavior of the users by analyzing them as big data. In this study, as a basic analysis of the number of steps, walking pattern was categorized based on the data of 1,598 users which was selected from the users of Tanita's "Body chart" service through data cleaning. Since the cumulative number of steps increases linearly, we analyzed the numbers of steps for one month (four weeks) for each age and sex group using GMM (Growth Mixture Model) and classified them into several groups [12]. Figure 3 shows the example of the result of the analysis for men in their 30s. In this example, the pattern of cumulative number of steps was classified into 4 groups.

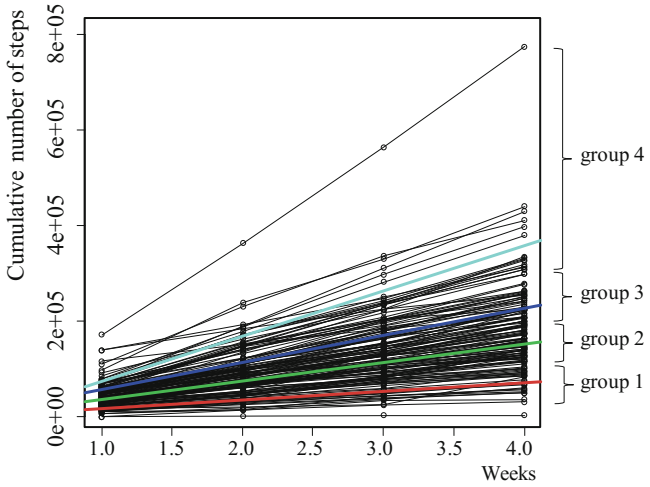

Fig. 3. Classification of cumulative number of steps (men, 30s).

Next, as for the relationship between number of steps and health condition, analysis of covariance on the relationship between the classification group of the number of steps and the visceral fat level was performed. For example, Table 1 shows the result of the analysis for men in their 30s. This result showed that there was no significant difference of visceral fat level for the passage of weeks in any age and sex, but there was a significant difference ($p < 0.05$) for the classification group. From this result, it was confirmed that the classification group of the number of steps correlated with the visceral fat level of the user, though there was no influence on visceral fat level by walking in about 1 month. Therefore, we can understand that for the user belonging to the upper classification group of walking leads to more healthy life.

Table 1. Result of analysis of covariance (men, 30s).

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Group	3	145.2	48.4	75.107	0.000 ***
Week	3	3.4	1.1	1.776	0.156
Height	1	17.2	17.2	26.633	0.000 ***
Weight	1	782.8	782.8	1214.723	0.000 ***
BMR	1	2.6	2.6	4.040	0.047 *
Muscle score	1	13.3	13.3	20.607	0.000 ***
Group × week	9	2.8	0.3	0.491	0.878
Residual	102	65.7	0.6		

3.3 Push Type Digital Signage

As health information feedback, user's smartphone and digital signage can be used. When a smartphone is used, the personal information can be displayed, but users cannot acquire information without accessing information by themselves. On the other hand, when a digital signage is used, though the personal information cannot be displayed without discretion, users can see the displayed information without doing any special action. In this study, we have developed a push-type digital signage that can identify the user who passes in front of it and display customized information to the user [13].

As a method of identifying user standing in front of the digital signage, the advertising function using BLE communication of the activity meter was used. The digital signage consists of a small PC (ZOTAC, ZBOX CI520 nano), a TV monitor (SONY, BRAVIA KJ-49X8000C) and a BLE communication receiver (ELECOM, LBT-UAN05C2). When the digital signage receives the ID information advertised from the activity meter, the owner of it is identified referring to the database and the customized information is created according to the individual. Therefore, the personalized information can be displayed automatically like a push message when the user comes near to the digital signage. Figure 4 shows the system configuration of the constructed push type digital signage.

When the displayed information is customized to an individual, it is expected that the user feels it as the information for himself and increases the attention to it. In addition, in order to maintain the user's interest, the effect of gamification was applied. Gamification is a method that introduces the elements of game that attracts the user's interest to other fields [14, 15].

Figure 5 shows a screen image of the health information digital signage that was designed by taking the effect of gamification into consideration. Displayed information consists of visualization graph, ranking table, cheering message, and health knowledge. The visualization graph shows the cumulative number of steps of the users by using the image in which the bar graph would reach the top of Mount Fuji if the user walked 10,000 steps every day for one month. By using this graph, the user's motivation of walking can be increased by utilizing the feeling similar to mountain climbing. The ranking table shows the rank order of steps in the members of the user's community

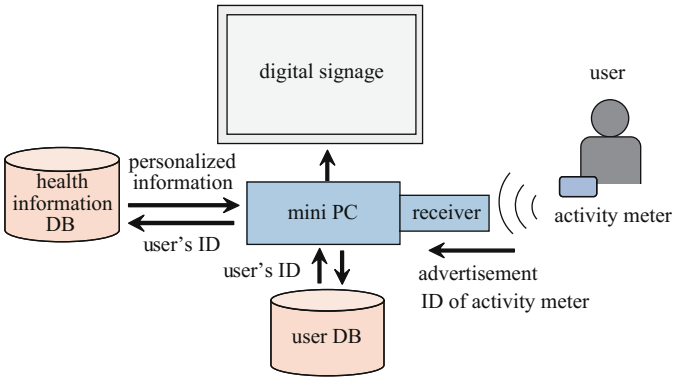

Fig. 4. System configuration of the push type digital signage.

and it aims to increase the user's competitive consciousness. The cheering message presents the message that encourages the user to walk or the next goal for the user according to the classification of cumulative number of steps. And the health knowledge presents various information that is useful for the user's health according to the classification group of the users.

By using the health information feedback, it is expected that the users can improve their health consciousness and health behavior of walking while enjoying it without changing their action consciously.

Fig. 5. Screen image of health information digital signage

4 Evaluation Experiment

4.1 Experimental Method

In this study, we conducted an evaluation experiment on the effectiveness of the health information feedback using the activity meter with BLE communication and the push

type digital signage. The purpose of the experiment is to investigate the influence of the health information feedback provided by the digital signage on the health behavior in everyday life.

As subjects in the experiment, three graduate students who have used the activity meter for more than 6 months were selected. The subjects were asked to use the activity meter with the advertising function, and the push type digital signage was installed in the student room. In this condition, the usage of the digital signage and the number of steps for each subject were measured for two months. In the measurement, the number of steps were recorded every day and every hour. Figure 6 shows that the push type digital signage is used by the user in the experiment.

Fig. 6. Push type digital signage used in the experiment.

4.2 Experimental Result

As an analysis for the experimental result, we conducted two-way ANOVA (analysis of variance) for the number of steps in one day on factors of subjects and use of digital signage. From the result, we can see that there was no significant difference for the subject, but there was a significant difference ($p < 0.05$) for the use of digital signage. Figure 7 shows the graph comparing the average number of steps in one day between the days when the digital signage was used and when the digital signage was not used. From the result, the number of steps in one day when the subjects used the digital signage was over 10,000 steps on average, though it was about 7,500 steps when they did not use the digital signage. Therefore, we can understand that the health information feedback affected the user's walking behavior.

In addition, we conducted two-way ANOVA for the number of steps in every hour on factors of subjects and use of digital signage. From the result, there was a significant difference ($p < 0.05$) in the number of steps at 9:00 to 10:00 and 11:00 to 12:00 for the subjects, but there was no significant difference at other time periods. As for the use of digital signage, there was a significant difference ($p < 0.05$) in the number of steps at the time of 7:00 to 8:00, 21:00 to 22:00, and 22:00 to 23:00. Figure 8 shows the comparison of the number of steps on the use of digital signage in each time.

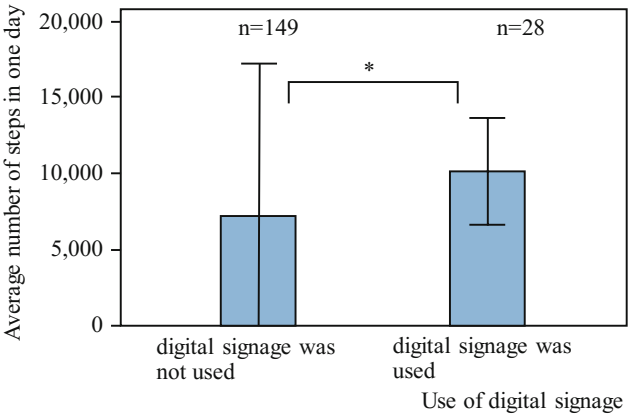

Fig. 7. Number of steps in one day for use of digital signage.

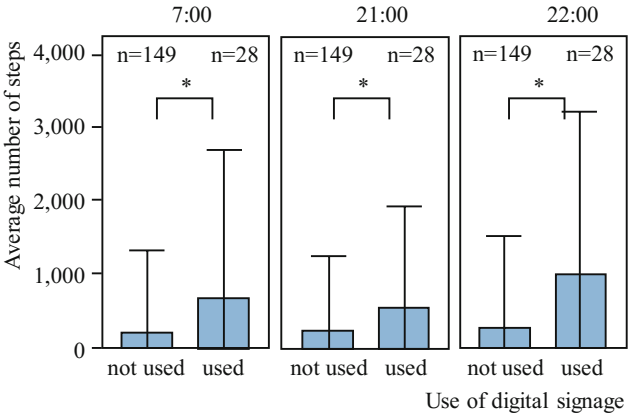

Fig. 8. Number of steps in one hour for use of digital signage.

From the result, it is considered that the difference in the number of steps on the subjects in the morning is due to the difference of life pattern such as commuting time. Also, in the morning and night time, there was a difference in the number of steps for the factor of the use of the digital signage. We can understand this means the users confirmed the data using the digital signage in the day when they walked more than usual in the morning, and the users walked more than usual in the night time in the day when they used the digital signage in the daytime.

Namely, it can be thought that the health information feedback affected the user's behavior in daily life and the change of the user's behavior led to use the health information feedback system.

5 Conclusions

In this study, as a service using the health log data, the framework for health information feedback was constructed to improve the health consciousness and health behavior of the users. This system aims to extend the healthy life expectancy of people by providing the health information based on the analysis of the health log data. In particular, in this study, we validated the effectiveness of the proposed system by showing that the use of the activity meter with advertising function and the push type digital signage affected the health behavior of the user through the evaluation experiment.

In the future research, we will advance the health log data analysis to derive various knowledge on the healthcare based on the big data analysis as well as consider various services that are provided based on individual characteristics of the user. Also, we will examine the method of not only providing information to the user but also recommending health behavior of what kind of action should be taken for the health in daily life.

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