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Personalized Recommendation of Health Behavior Using Mobile Device Based on Health Log Data

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Abstract
Ideal health behaviors are different for individuals in terms of their own health condition and life style. Individuals should follow he
alth behavior which fit their situation. The purpose of this research is to investigate the effectiveness of personalized health behavior recommendations in helping people who have health conscious to live a healthy lifestyle. People with high blood pressure, lack of exercise, and cold sensitivity are targets of this research. The recommendation system is implemented as a mobile app, and those recommendations are delivered through the mobile device as push notifications. The contents of health behavior recommendations are personalized based on user information about health condition, life style, and health log data while using the system.
As a result of users' habit that they consistently carry mobile devices with them, health behavior recommendations reach users seamlessly as real-time notifications, and effectively remind users to keep those behavior. The personalized contents constructed based on users' information and log data help them to stay motivated to be healthy, since the contents fit their situation. The case studies on people with high blood pressure, lack of exercise, and cold sensitivity indicate the personalized health behavior recommendation using mobile device is effective to improve users' health condition through recommending health behavior which fit for them.

Key words : health behavior recommendation, push notification, health log data, lifestyle, mobile application

1. Introduction

Nowadays, with the progress of science technology and the development of medical system, the average life expectancy would be lengthened. However, healthy life expectancy does not increase at the same rate, since modern people tend to have unhealthier life behavior than past. Here are around 10 years gap between average life and healthy life expectancy. Based on WHO (World Health Organization) statistics (GHO, 2016), the data of average life and healthy life expectancy of World, Japan and China shows this marked difference (Fig.1 and Table.1). It is obvious that an amount of aged people are in sub-health status for a long time because of unhealthy life behavior.

In Health Japan 21, a project by Japanese government, health management could be divided into diet and nutrition, physical activity and sleep. A well-handled health management could be started from these three fields. As a result, this project is committed to help users to develop a healthy behavior with application in smartphone.

Here are some related works, which using modern technology into health care. For example, the amount of data being digitally collected and stored is vast and expanding rapidly. The big data management and analysis would be applied to health care and developed applications (Murdoch, et al., 2013). In addition, discrete-event simulation software technology is also used in health care to allocate scarce resources to improve patient flow and minimise health care delivery costs and increase patient satisfaction (Jun, J B, et al., 1999). But this research focus on personalized recommendation in daily life to help users develop a healthy lifestyle.

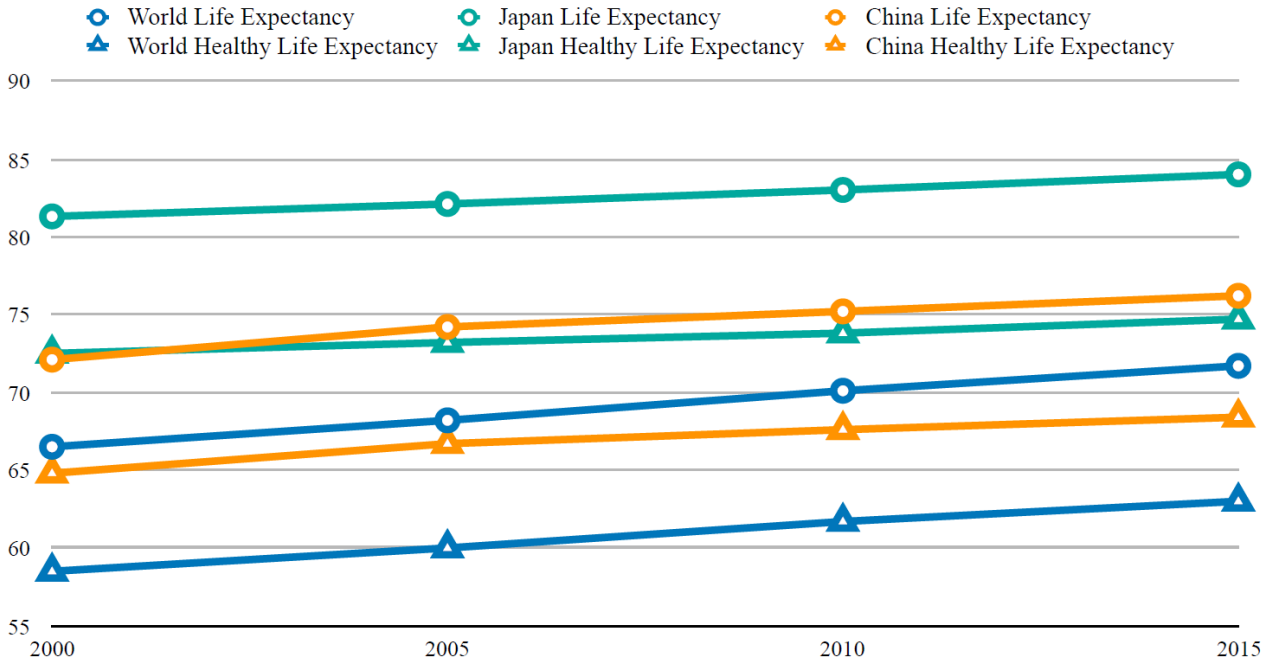

Fig. 1 Average life and healthy life expectancy

2. Concept of health behavior recommendation system

The concept of health behavior recommendation system (Wiesner, Martin, and Daniel Pfeifer, 2014) is changing users' behavior on daily life and making them to be motivated to be healthier by providing appropriate recommendation to the users at appropriate situation using the push notification message of the mobile device. It is also call mhealth, which means using mobile phones and other wireless technology in medical care, the most common application of it is educate users about preventive healthcare services(mhealth, World Health Organization, 2011.). The targets of this research are people with high blood pressure, lack of exercise, and cold sensibility. The contents of health behavior recommendation messages are personalized based on user information about health condition, life style, and health log data while using the system. Thus, the appropriate message can be constructed. It is also important that the personalized recommendation message is presented in an appropriate situation to improve the user's behavior. Appropriate situations refer to diets, physical activity, and sleep that are important for health management. Then, the recommendation message can change the user's behavior in diets, physical activity, and sleep. From the above, it is expected that the health behavior recommendation system improves the user's daily behavior and lead the user to a healthier state (Pattaraintakorn, Puntip, et al., 2007).

3. System construction

The recommendation system was implemented as an iOS application in which recommendations on health behavior are delivered to the user as notification messages. The notification contents are personalized based on the user's health condition, life style, and health log data. They are triggered by time and location, even the application is not running or in the background, the system still could interact with the user, if the application is in the foreground, the notification message would be delivered in application for handling(Apple developer documentation). Therefore, the contents of displayed recommendations vary with these factors, as shown in Fig.2. For health conditions, this system focused on three cases which are high blood pressure, lack of exercise, and cold sensitivity.

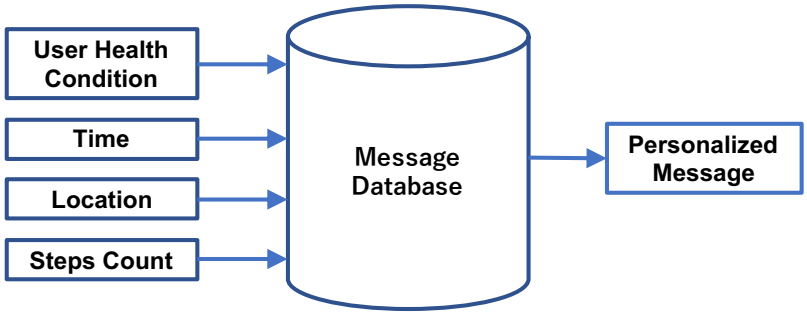

Fig.2 System overview

3.1 Health Condition and Life Style

User's health condition and life style are set in the user setting view as shown in Fig.3. When the application is launched, the top view will be displayed, which includes a tips list for healthy life, the current steps count, and a comment about the current steps count status. For setting life style, user can input his or her workplace coordinate, home coordinate, get up time, breakfast time, lunch time, dinner time, and sleep time on the user setting view. The user can also set his or her health condition from life style diseases which are high blood pressure, lack of exercise, and cold sensitivity. For inputting workplace and home coordinate, the user can pin the location from maps and the chosen place will be automatically inputted to the blanks in the user setting view. After the user saves setting and quit the application, he or she will receive health recommendation messages which are selected from message database to fit his or her own health condition and lifestyle.

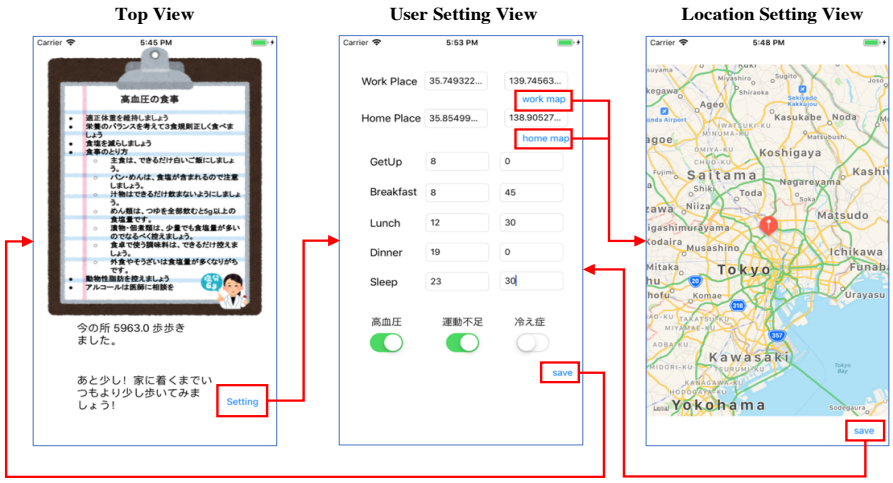

Fig. 3 Setting of health condition and life style

3.2 Health log

HealthKit allows applications to access Apple's Health App which records multiple user activities regarding health care, such as steps count, body weight, and body temperature. As described in Fig.4, this application accesses Health App using HealthKit, and read current steps count to display it on application's top view. Furthermore, the desirable steps count for an adult per day is 10,000 steps (Iwane, Masataka, et, 2000), so this application will motivate users to walk more when steps count is less than 10,000, and compliment users when steps count is more than 10,000. In addition, the data read from HealthKit such as steps count, body weight and body temperature can also be used to select push message from message database to personalize the displayed message.

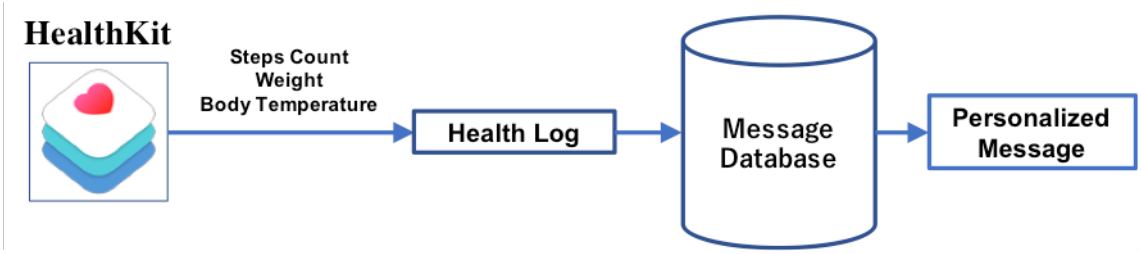

Fig. 4 Usage of health log data using Health Kit

3.3 Time based notification

Recommendation notifications are triggered based on times set by the user, which are get up, breakfast, lunch, dinner, and sleep time. These recommendations fit with the user's health condition which is specified when setting. For example, when lunch time, the user with high blood pressure will be advised to eat less salty food (Chobanian, A.v., et al., 2013); the user who is lack of exercise will be advised to eat more vegetable (Booth, Frank W., et al., 2012); the user with cold sensitivity will be advised to eat more high-protein foods (Dale Collins, MD E, and MSChristine B Novak., 1996).

3.4 Location based notification

Recommendation notifications are also triggered based on locations set by user, which are workplace and home locations. The system monitors the location of device and deliver notifications to the user when he or she enters and exits the region of set locations. The radius of region is set to be 1 kilometer. For example, when the user who is lack of exercise is getting near to home on a bus, the system will recommend him or her to walk the last 1 kilometer.

3.5 Push Messages

After setting times, locations, health condition, and life style, users can receive notification messages even when they quit the application and use mobile device as usual. The system will recommend appropriate health behavior at appropriate situation as shown in Fig.5.

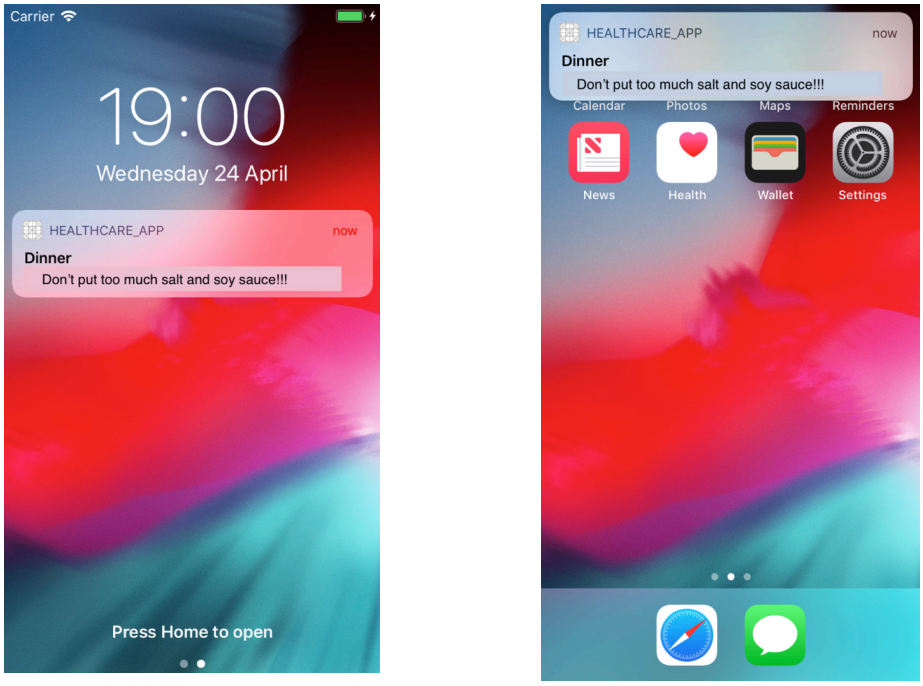

Fig. 5 Notification on locked screen & unlocked screen

4. Evaluation experiment

The contents of a mobile app (health behavior recommendations) are personalized based on user information. The examinee (high blood pressure, lack of exercise, and cold sensitivity) used a mobile app for two weeks and recorded the data such as blood pressure, body weight and the steps count, and body temperature and hands and foot temperature by using a thermometer and thermography camera. After the two weeks experiment, we saw how the mobile app effected their health awareness, activity and condition.

4.1 Examinee information

As already written, we set three cases which are “high blood pressure”, “lack of exercise” and “cold sensitivity”. There is one examinee who fits health condition for each cases and their basic information is described in Table1.

Table1 Basic information of examinees

Case	Sex	Age	Demographics
High blood pressure	female	55	part-time job
Lack of exercise	male	52	full-time worker
Cold sensitivity	female	23	student

●High blood pressure

She lives with two children who are 26 and 23 years old and works at a select shop four days a week about 7 hours (11:00am to 19:00pm) for a day. The select shop which she works at is 1.5 hours from her house by train and basically she sits in front of computer all day except when customers appear. She has had high blood pressure for about ten years and been taking two kinds of medicine which are Amlodipine and Rezaltas combination tablets HD after dinner every day to bring down the blood pressure for about 5 years. Her average blood pressure level in morning is 130/85 mmHg.

●Lack of exercise

He seldom has an opportunity for an exercise and it became worse since he started studying at graduated school. His weight was 81.1kg at the beginning of the experiment and average number of steps per day is 8000 (6.5km). He lives by himself and is a full-time worker and usually works 5 days a week about 8 hours (9:00 am to 18:00 pm) for each day. It is about 30 minutes by train from his house to the office which is directly connected with the nearest station, and it is only 2 minutes by foots from his house to the nearest station.

●Cold sensitivity

She has a cold sensitivity and her average body temperature at the beginning of the experiment was 36.4 C. She lives with family (father, mother and younger brother). She is a college student who goes to school 5 days a week, and it takes about 1 hour from her house by train. And she usually spends at school from morning to evening (9:00 am to 18:00). She has a part time job which is at KidZania and works once a week and belongs to YMCA (The Young Men’s Christian Association) and joins a meeting once a week and its activity once a month.

4.2 Push messages which examinees receive during the experiment

As already written, the push messages contents of the mobile app (health behavior recommendations) that examinees receive are personalized based on examinees’ information. Message contents are mainly focused on their daily diet, exercise and sleep. Some examples of messages that they actually get during the experiment are described in

Table 2. Displayed message is selected randomly from the messages stored in the data base.

Table 2 Some examples of messages that they actually get during the experiment

Case		Message
High blood pressure	1	Be careful of too much salt and soy sauce intake!
	2	Too much stress causes high blood pressure, so take it easy!
	3	Get enough sleep and getting rid of tiredness leads to decreasing blood pressure!
Lack of exercise	1	Don't forget to have a breakfast and it is connected to spend a day more active!
	2	Let's go to outside to catch a Pokemon for a change!
	3	Use stairs instead of taking elevators and escalator!
Cold sensitivity	1	Adding soup or hot drink to usual meal, it warm your body up!
	2	Take exercise and develop muscles. It leads to the improvement of a cold sensitivity!
	3	Take a warm(40~42℃) bath for 10 minutues!

4.3 Devices which each examinee used for the experiment

For conducting the experiment, each examinee recorded data which was needed for each case such as blood pressure, body weight and body temperature. The devices such as an electronic sphygmomanometer (UA-651BLE, A&D Company, Limited), a weight scale (UC-352BLE, A&D Company, Limited), and a thermometer (UT-201BLE, A&D Company, Limited) are equipped with BLE communication function and the data was recorded in "Health" app in the user's smartphone automatically. Also, for a cold sensitivity, in addition to body temperature, the examinee recorded foot and hands temperature by using thermography camera (FLIR ONE Pro, FLIR system) which is equipped with iPhone. The devices which were used for the experiment are shown in Fig.6.

●Electronic sphygmomanometer for high blood pressure

●Weight scale for lack of exercise

●Thermometer for cold sensitivity

●Thermography camera for cold sensitivity

Fig.6 Devices which were used for the experiment

5. The result of the experiment

The results of two weeks experiment are shown in Fig. 7 to Fig. 14. Also, we had a questionnaire with them about how their health awareness such as diet, exercise and sleep has been changed through using the application.

5.1 Change of log data

●High blood pressure

At the start of the experiment, the blood pressure levels were 126/89 mmHg and it changed to112/75 mmHg at the end of the experiment. Some decrease was seen and it is shown in Fig.7 and 8.

●Lack of exercise

At the beginning of the experiment, the body weight was 81.1 kg and at the end it was 79.9 kg, which lost about 1 kg. Although it decreased to 78.65 kg temporarily, it seems that weight loss stagnated due to the influence of having a long-term vacation and having a different lifestyle from usual (Fig.9 and 10).

●Cold sensitivity

At the beginning of the experiment, the body temperature was 36.65 C and at the end it was 36.1 C. Little change was seen (Fig11-14.).

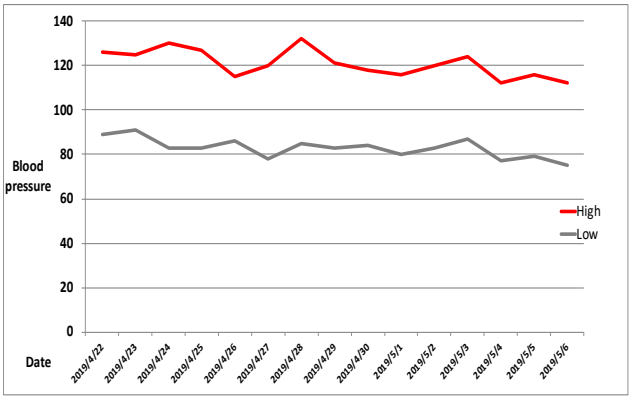

Fig.7 Blood pressure change during two weeks experiment

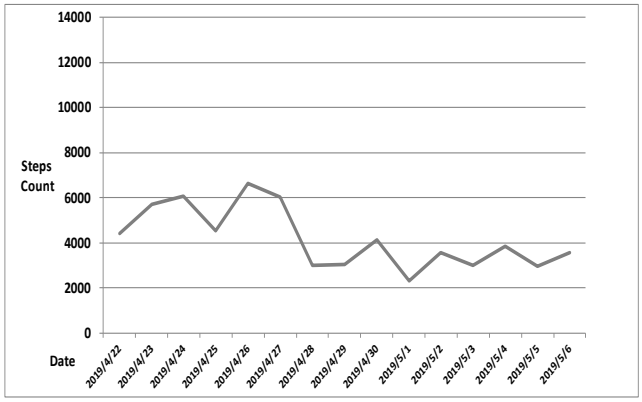

Fig.8 Steps count during two weeks experiment

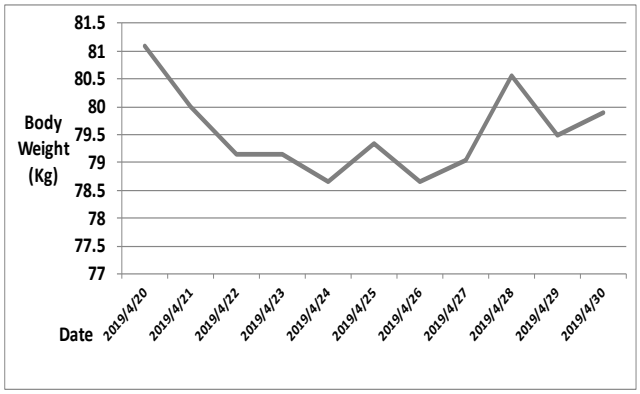

Fig.9 Body weight change during two weeks experiment

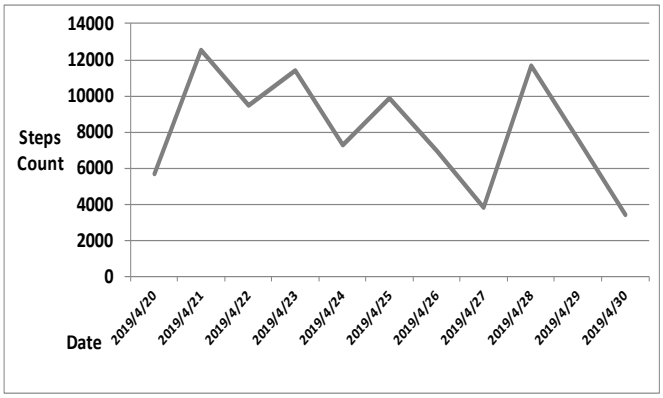

Fig.10 steps count during two weeks experiment

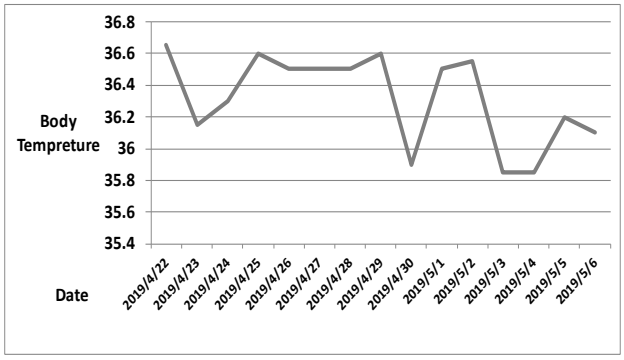

Fig.11 Body temperature change during two weeks experiment

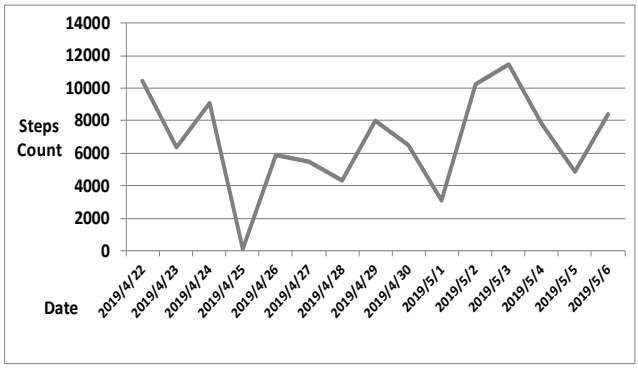

Fig.12 steps count during two weeks experiment

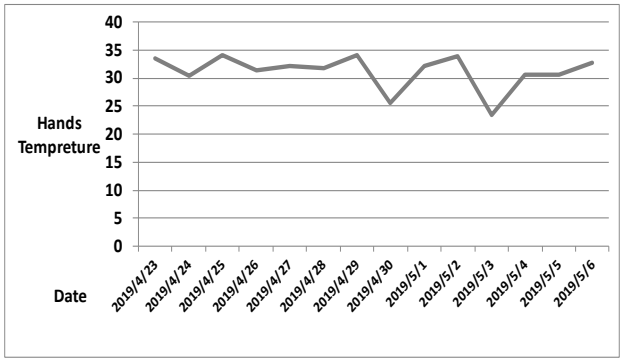

Fig.13 Hands temperature change during two weeks experiment

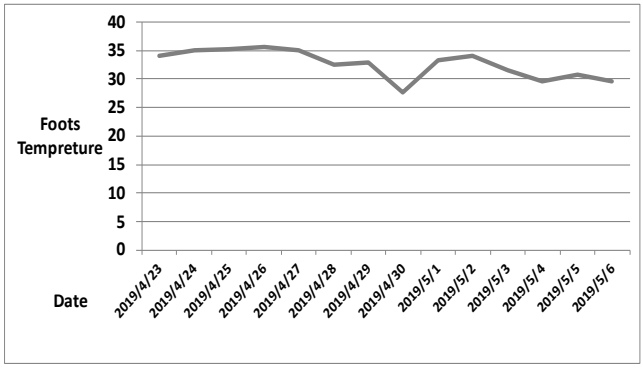

Fig.14 Foots temperature change during two weeks experiment

5.2 Questionnaire for examinee after the experiment

In the questionnaire, there are three questions about application which are effectiveness, availability, and whether they would like to continue using the system. As for effectiveness, examinees evaluated it on scale of 1 to 5 and answered whether there was an awareness change in terms of diet, exercise and sleep. They evaluated it as 3 and answered that it affected their awareness of over-eating, walking well, and one of them realized her irregularities in sleeping time and stopped night owl. As for availability, it was also evaluated on scale of 1 to 5 and whether there was a problem. Their evaluation was pretty high which was 5 or 4. On the other hand, there were negative opinion about its function such as the less variation of messages and inability of viewing past records in the application. About whether they would like to continue using the system, two of examinees answered positively, however, one answered negatively and she said “other existing applications are enough and it is lack of uniqueness”. This means that displayed message seemed to be conventional for the user and appeared less personalized. Thus, there is some room to use online health log data effectively and increase the variation of the displayed message.

6. Discussion

The recorded health factor data of examinees having tendency toward improvement and positive comments about the push notification system that it has positive influence on examinees to behave healthy life style indicates that the system is effective to improve users' health behavior through notifying recommended behaviors. Since examinees did not always act as times set, such as lunch time and dinner time, notifications sometimes did not appear at the appropriate time. Instead of sending notifications at time which is set by user, a more accurate mechanism should be implemented to monitor user's behavior, thus recommendations can be delivered at more appropriate time. Furthermore, health behavior should be recorded for a longer period of time to investigate the effectiveness of push notification on changing user's behavior toward healthy life style.

7. Future

The notification to the user is based on local notification system and the function is limited so far. For instance, the content and time of the notification are hard to change. Also, more customized messages are unavailable. If we want to build a more user-friendly system and push more specific messages to users, the use of the server is very necessary. In the next stage of the research, the server will be used in this system and more functions will be available. In addition to the user's daily push, health-related news link pushes can also be implemented. At the same time, it is also possible to push the content of recommendations for healthy living to users with different characteristics such as underactive and high blood pressure. Furthermore, the user data can be stored in the database on the server, and the content, frequency, time and mode of the remote push notification can be changed according to different habits of the user.

8. Conclusion

For the healthy problem in present-day society, an application which could push health behavior information was developed based on health condition, life style, and health log data, in order to build personalized health behavior recommendations system and help users have a healthy lifestyle. To push the personalized information to the user, user's health condition, life style, time, location and health log data would be used to select and trigger the appropriate message from the database. The case studies on high blood pressure, lack of exercise, and cold sensitivity indicated that this health behavior recommendation system improved users' health condition effectively.

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