

퍼스널 헬스케어 디바이스 사용자 경험 연구

Explicating Personal Health Informatics Experience

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요약

최근 헬스케어 산업의 증가와 웨어러블 디바이스 및 건강 관련 모니터링 기술의 발전은 자신의 행동을 측정하고 계량화하는 자아정량화 운동의 부흥을 촉진시키고 있다. 퍼스널 헬스케어를 통해 사용자들은 자신의 건강관련 행동을 정량적으로 인지하고 건강관련 인식을 향상할 수 있게 되었다. 본 연구는 사용자에게 전달되는 건강정보를 보다 효과적으로 전달하는 방법을 찾고 제안하고자 한다. 이를 위해 어플리케이션에서 피드백 유형(feedback type)의 비교반응과 정보 제공형태(presentation mode)의 심리적 효과에 대한 실험연구를 진행하였으며 이를 위해 피험자들의 건강 자가보존 성향을 측정하였다. 실험연구 결과, 비교조건과 텍스트 조건에서 사용자의 개인정량화 정보를 효과적으로 전달하는 것으로 나타났다. 또한 피험자의 건강 관련 자가 인지에 따라 건강 자가보존 성향 역시 증가하였다. 이러한 연구 결과 분석은 사용자의 건강 관련 행동 변화 유도의 관점에서 건강정보학 분야 연구의 사용자 행동유도성에 관한 학술적 방법론에 기여할 수 있으며 개인정보학 어플리케이션 설계 및 개발에 의미있는 기여를 할 수 있다. 또한 연구결과는 향후 웨어러블 디바이스의 지속적인 사용을 위한 요인 분석과 개인 트래킹 데이터 분석을 통한 효율적인 건강관리 등 헬스케어 산업에 새로운 통찰을 제공할 것이다.

■ 중심어 : | 자아정량화 | 개인의료정보 | 웨어러블 | 사용자경험 | 정량자기 | 퍼스널 인포매틱스 |

Abstract

Recent advances in wearable devices and quantified-self movement increase the number of personal informatics application that may cause an concern to health industry and user. In this light, the goal of this study is to identify more effective ways of design and evaluation of personal informatics application for self-tracking and delivering health information to users. For this goal, this study conducted areal-world study that processes such that user can assess, be aware of, and self-reflect on their data and behavior activity. In doing so, this study aims to determine the psychological effects of forms of health feedback (comparative vs. non-comparative) and presentation modes (text vs. image) on users' tendencies toward health conservation. Results from a between-subjects experiment revealed that health information in a comparative and textual format was more effective in encouraging health conservation in participants than identical information presented in a non-comparative and image format. In addition, participants' level of health consciousness emerged as a significant predictor. Through this analysis of quantitative data and inferences, this study make a number of contributions to the user affordance research and its methodology of health informatics study and designing personal informatics application that support user's behavior change in various contexts.

■ keyword : | Personal Informatics | Quantified Self | Wearable | Health Behavior & Experience | Feedback Type |

I. Understanding Self-Tracking

Small electronic devices that track people's activity, sleep, and diet, called self-trackers, are being widely diffused. It is worthwhile to investigate the user experience and the effectiveness of these devices, and use the information toward designing better devices that would result in increased usability and affordance.

One of the oldest recorded examples of Quantified Self-tracking is that of Sanctorius of Padua, who studied energy expenditure in a living system by tracking his weight versus food consumption and elimination for 30 years in the 16th century[48]. More recently, in a 2013 US nationwide survey on health tracking practices, it was reported that seven in ten US adults tracked a health indicator for themselves or for others[6][18]. Basically, the Quantified Self (QS) concerns an individual engaging in self-tracking and self-monitoring. Self-monitoring refers to the recording of one's own target behavior[34]. Self-monitoring induces positive effects in the observed behavior, resulting from the practice of self-tracking[29].

Wearable devices, such as smart watches and activity trackers, have become increasingly popular tools for the Quantified Self. These devices monitor and collect health-related data and help users review personally relevant information[31]. The collected data are used for self-reflection, which allow users to become more aware of their own behavior[36] and to positively change their conduct in regard to health conservation[15][44].

Prior studies on the Quantified Self and personal informatics have researched topics that are relevant to people's daily lives, such as exercise, general health, and finance[31]. Among these, health-related subjects have become the most popular; consequently, many information and communication technology (ICT) companies are competing to release wearable

devices that feature health-related functions. Such functions include the monitoring, collection, and presentation of information concerning quality of sleep, distance traveled, and calories burned.

The Quantified Self movement has received a lot of attention in the last several years. It is characterized by a wearable device collaboration tool like 'Fitbit' and is a fundamentally new way to develop human data that poses a serious challenge to commercial wearable devices and other businesses dominating software markets today. The present study focuses on the effect of application interactions on the health perceptions of users in a Quantified Self movement project from the viewpoint of the research field of human-computer interaction (HCI). Application development is traditionally a coordination-intensive process and has attracted several HCI researchers[3]. Human-centered software is developed by geographically dispersed programmers with the aid of wearable technologies such as data information management systems[50]. To design personal informatics systems, inspiration is taken from works in the areas of design and data interaction[45][50].

The research presented in this paper is an attempt to determine whether different social visibilities and awareness affect the interactions in a Quantified-Self system. The results of the condition classifications were compared with the quantified behavior patterns that occurred within each condition in order to determine whether there were differences among groups based on use of the personal informatics system. The study results provide new insights for determinants of engagement of self-tracking through personal informatics software and applications.

From a theoretical perspective, the effects of mode (text vs. image) on user behaviors have been researched extensively[53]. Amongst numerous research, it has been argued which mode is more

effective and what method is more significant in delivering health information to users. This study focuses on this inquiry. In so doing, this study has contributed to the literature by applying the framework into the emerging QS movement. While various mode may arise with the drastic development, the fundamental model will provide us with insightful answers on the mode and user experience.

From a usability and design perspective, it is important to develop an effective user interface or method for delivering health information in order to promote preventive health. Therefore, this study manipulates feedback types and presentation modes as potential strategies for increasing the positive impact of health information and examines the effects of these forms of feedback regarding user health behaviors. In this way, the present study intends to provide a more robust understanding of how various feedback styles and presentations influence the effectiveness of feedback on self-monitoring and, ultimately, health behavioral changes. This study contributed to QS literature by addressing the user experience of QS adopters, where a number of questions arise at the interface of health and information technology.

II. Literature Review

2.1 Personal informatics for human-data interaction (HDI)

Quantified-self is an important flow of human activity data and engagement, motivation. In these personal data can describe in Human-data interaction perspective[21]. Given all components of the Personal informatics on human data interaction, there are some important perspective that people could adopt in planning and interacting their Personal informatics

system applications. It is focus on a level that the question of what and how their data include on their own activity or life[21]. To find people's purpose in the Personal informatics and self-tracking, many research showed to envision a broad end-user for data-driven interaction[21].

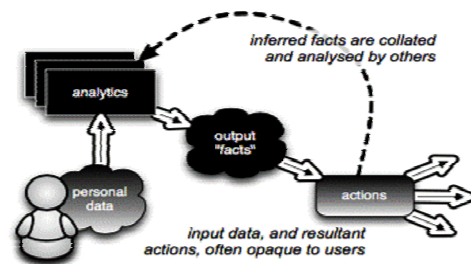


Fig. 1. An illustration of the human-data interaction framework[21]

Several Quantified Self applications promote healthy behaviors through design and evaluation of various technologies, in which self-monitoring components are often embedded[7]. Specifically, data collection, data analysis, and data sharing are the means through which individuals can assess, be made aware of, and self-reflect on their behaviors. These forms of data can influence individual decisions and the social mind[21].

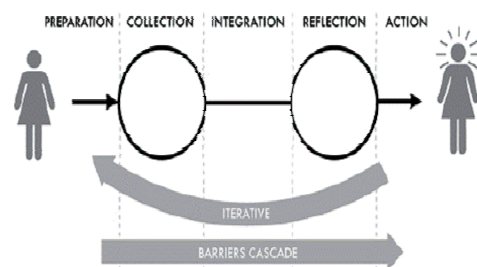


Fig. 2. Li et al.'s five-stage model of personal informatics. Reprinted with permission[31]

A stage-based model of a personal informatics system describes five stages of data barriers [Fig. 2][31]. The first step includes deciding what information to record and how to collect it; second, collecting data; third, integration of data; fourth, reflection or examination of data; and fifth, change as a result of this new information[31].

The Trans-theoretical Model of Behavior Change (TTM) is based on this model[39]. Practices of the Quantified Self show that the reflection stage often occurs when data is captured[9] and proposes a new model for self-monitoring technology of reflection through data capture and feedback[6].

2.2 Self-monitoring via quantified self

Self-monitoring refers to the recording of one's own chosen target behavior[34]. This monitoring includes subjective information (e.g., a problem, situation, symptom, or disruption that symptoms may produce, as well as inner thoughts or feelings) and objective information (e.g., frequency or intensity of a behavior under observation). Previous theoretical work from psychology provides critical insights to the design of self-monitoring technology[32]. Primarily informed by tracking behavior change, the model emphasizes data barriers to a presumed action. We extend this model to characterize challenges in a rising informatics.

To promote health behavior change, researchers and designers often use technology to monitor health-related activities. Both research and commercial applications have incorporated automated sensing or manual tracking within technology applications to help people monitor and reflect on their behaviors. The field of Personal Informatics and the Quantified Self movement (<http://quantifiedself.com>) both adopt the approach that knowledge of one's activities allows one to reflect on those activities, make

self-discoveries, and possibly use that knowledge to make changes. Within the health domain, both research and commercial applications have focused on tracking activity[6][8].

Many research areas also focus on collecting self-tracking data and personal information[52]. Life logging research explores the use of sensors to collect various types of information about people's daily lives. The developers of MyLifeBits[51] envision a future where daily activities of people, such as computing, web-browsing activity[6], electronic communication, and media usage, are recorded and archived. SenseCam, a wearable digital camera, takes photographs throughout the day while worn by the user[6][52]. The device also contains other sensors, such as light sensors, an infrared detector, and an accelerometer[6].

2.3 Self-monitoring applications

Visualization is the key way to gain insights from data, and a Quantified Self application (app) offers combined visualization composed of line charts, stacked bar charts, and tables on the app dashboard [1]. The dashboard also engages the self-monitoring perspective that refers to an individual recording the occurrences of his or her own target behavior[34]. The types of information collected during self-monitoring are diverse, ranging from subjective information (e.g., a problem, situation, symptom, or disruption that symptoms may produce, as well as inner thoughts or feelings) to objective information (e.g., frequency or intensity of a behavior under observation). Self-monitoring technologies facilitate recording of the occurrences of target behaviors and provide feedback to help individuals increase awareness and self-reflection[9]. In order to properly present a user's working activity and self-monitoring information, the device must be paired to a user

account, and data can be offered on a dashboard menu. By synchronizing user activity to the app, users can view their steps and distance over time, graph their weight changes, view their food intake versus caloric burn, see how well they are sleeping, and more. A 'Challenges' menu on a Quantified Self app is a way to keep users motivated by competing with friends, family, and or themselves. For example, up to 10 people can participate in each challenge; if you initiate a challenge you can invite your friends, and those friends can invite their friends. A good example of a Quantified Self movement device is the Fitbit. Fitbit is an activity tracking, wireless-enabled wearable device that measures data such as the number of steps walked, quality of sleep, and other personal metrics. Fitbit offers a mobile app that users can use to track basic activity and runs, or the user can connect to Fitbit's line of activity trackers and the Aria Smart Scale to obtain a complete picture of daily stats—including steps, distance, calories burned, sleep, weight, etc. Challenge participants can also see other users' profile photos, posted messages, total steps in the challenge, goal progress, and achievements. Some users have voiced concern due to the negative stigma associated with rewards and an overall push toward gamification[2][14]. Badges are used to encourage users to enact certain behaviors or meet particular goals. Some Quantified Self applications like Fitbit offer a 'Friends' menu that enables users to compete with their friends. Comparison refers to contrasting one's achievements with one's own past performance or to the performance or abilities of other individuals (i.e., comparison targets)[37]. Comparative feedback is a motivating factor in health communication that promotes behavioral changes in areas such as health and exercise[11]. Previous research on the motivation behind behavioral changes has shown that significant

improvements can be achieved through comparative feedback[37]. The results from the previous studies have consistently shown that users who have comparative feedback are more engaging and more likely to actively involve with the health services than those non-comparative feedback. Wearable activity trackers such as Nike+ also compare a user's fitness data (e.g., steps taken, distance traveled, calories burned, and quality of sleep) with data of other users. Although tracking tools make an effort to increase self-awareness and self-motivation, it is difficult to capture and provide direct engagement with data collection. People may become complacent and forget about their goals. Therefore, when designing an app that automatically senses user activity, designers need to create an engaging user experience. In order to achieve this, the data interface needs to have a low mental workload and high data accuracy. Moreover, activity cues are needed to encourage engagement. For example, the Quantified Self app is not only designed as a wearable sensing device (accelerometer) to track physical activity, but it also allows users to manually add food, mood, and water consumption related to activity and offers notifications to the user.

2.4 Social feedback and behavior change

Data can help people to become aware of their own behaviors[4], make better decisions[16], and change behaviors ranging from health to energy conservation[30] using the principle of comparison, as discussed above.

Theories of health behavior change have been studied in the field of psychology, even though the design of technologies to change people's behaviors is a relatively new concept[18]. Behavior change theories specify the determinants and relationships that influence people's behaviors and also explain how

changes in determinants lead to behavior changes based on reliable assessment measures and predictive validity.

It is important to design health technologies based on an understanding of behavior change theories. Designing health technologies in combination with various behavior change techniques and theories often makes it difficult to determine which design elements produce the intended behavior outcome[28]. To resolve the ambiguity and complexity of applying theories in design, there are three ways of applying theories in HCI research[23]. First, theories can be used to generate “design hypotheses” that require subsequent tests to validate the efficacy of the technology. Second, theories can guide the evaluation strategies of behavior change technologies, for example, by delineating conditions and defining measures[25]. Lastly, theories can be used to determine target users. This case is exemplified in the use of the transtheoretical model[39] by examining individuals in phases of the model. The following summarizes the theoretical background of self-monitoring and framing effects.

2.5 Difference of this study from previous research

Literature reviews show that previous studies duly have addressed the issues ranging from quantified self, personal informatics, self-monitoring behavior, and human-data interaction. Such research have examined such topics, but none of them has focused on emerging quantified self technologies. Furthermore, their approach either technology-oriented or purely users’ psychological dimension underplaying the interaction perspective of quantified self and user behavior. For the gap, this study focuses on the interaction and contextual perspective, examining user behavior in their actual interaction with

quantified self. This study examines the user behaviors in their context of livings and during their actual interaction with quantified self. In behavior research domain, framing effects are refer that and related psychological effects of presentation mode (e.g., text, audio, image, video) and decision research. Regarding people’s decision revealed that presenting the same option but varying the framing of acts, contingencies, or outcomes alters people’s motivation. Meanwhile, in health communication domain or health informatics on human computer interaction research, prior research does not address how to best present daily near performance feedback that can lead to health-enhancing, self-beneficial decisions.

III. METHODS

With the advent of the Quantified Self movement and the wearable device era, increasing emphasis has been placed on investigations of human-data relationships and human-data interaction in order to explore ways to provide a more genuine and socially meaningful Quantified Self experience. One of the critical aspects of human-data relationships is the extension or projection of user preservation regarding health onto an object and the delivery of activity information, which largely determines user satisfaction with and perspective on their activity or visualization of their data[54]. The present study aims to investigate these issues. To verify the research goal, the current study examined the following research questions (RQs) through an experimental and quantitative approach:

RQ1: How does the Quantified Self application help users promote healthy behavior change?

RQ2: How can we design persuasive performance feedback to enhance individual self reflection and health conservation?

2-1: For Quantified Self movement users, controlling for health consciousness, what are the effects of presentation mode (text vs. image) on health conservation tendencies?

2-2: For Quantified Self movement users, controlling for health consciousness, what are the effects of feedback type (comparative vs. non-comparative) on health conservation tendencies?

RQ3: What are the interface design implications for a Quantified Self application?

To answer RQ1, in order to understand the current landscape of human-data interaction and the Quantified Self, we conducted empirical research. The goal was to identify challenges and opportunities for personal informatics system interfaces to promote user health conservation. To address RQ2 and RQ3, this study designed and developed an Android application using four types of Quantified Self feedback focusing on comparative feedback and presentation modes. We also studied the effects of different feedback designs on user health conservation.

3.1 Research design

The present study examined ways to promote user health conservation and healthy behaviors through design and evaluation of various Quantified Self applications and technologies, in which self-monitoring components from comparative feedback are often embedded. Specifically, the research design contained three main process and interrelated steps of self-monitoring: data collection, self-reflection, and data-related health behavior change. The goal of this study was to support these processes to enable users to assess, be conscious of, and reflect on their health behaviors.

In the health informatics domain of human-computer interaction, several studies have shown the effects of self-tracking feedback on user perceptions using survey-based methods rather than experimental

research. Recent research on personal informatics is also experimental research, survey or social data-driven research. Therefore, we designed experimental research and procedures based on Li et al.'s five-stage model of personal informatics [Fig. 2]. First, we conducted a pilot test of a material interface design with a text mode and walking map visualization using the example of the Nike+ fitness tracker.

The main experiment was created from results of the pilot test. A between-subjects experiment was conducted, with four conditions representing two types of feedback (comparative vs. non-comparative) and two presentation modes (text vs. image). The apparatus consisted of a wearable device with a 1.6-inch screen (SONY SmartWatch2) and a tablet computer with a 7-inch screen (Google Nexus 7). These were paired via Bluetooth connection that prepared in the lab. Both devices' brand names and logos were masked to avoid potential effects of brand familiarity and preference.

Table 1. Background information of survey respondents (N=40)

	Item	Percentage	Numbers
Sex	Male	45	18
	Femal	55	22
Age (years)	19 ~ 24	78	31
	25 ~ 29	22	9
Wearable Device Ownership	Yes	8	3
	No	92	37
Usage of Personal Informatics System	Yes	18	7
	No	82	31

3.2 Participants

Internet-based recruitment was used to gather participants for the main experiment in this study. Forty undergraduate and graduate students were recruited, all of whom stated that they did not own a wearable device. The ages of these participants

ranged from 19 to 27 years, with an average age of 23 years. The participants were paid for their participation.

3.3 Experimental treatment conditions

To manipulate self-monitoring feedback type, participants in the comparative feedback condition received a message that compared their calorie burning exercise with that of a friend (e.g., “You walked 300 meters and burned 20 calories. A previous participant walked 400 meters and burned 25 calories”). However, those in the non-comparative feedback condition the message only about their own behavior.

To manipulate presentation mode, participants in the text mode condition received the above message purely in a textual format. In the image mode condition, the message included a map that showed the routes taken by participants.

3.4 Application implementation

The Quantified Self application was implemented as an Android app [Fig. 3, 4]. Each feedback condition, such as comparison and visualization, was implemented using the Google Maps API (Application Programming Interface) and the Google Charts API. These web APIs were ported for the Android system. The smartwatch device used a Sony smartwatch default app to connect to the Android application via Bluetooth. All other graphical views were implemented with Android Material Design, which provides rendering methods.

3.5 Procedure

A pretest was undertaken to examine the main test for test-retest reliability and construct reliability before conducting the experimental study. Eight undergraduate students in university in Seoul, Korea with knowledge of and experience with wearable devices and the Quantified Self (and other similar experiences) participated in the pretest within a 2-day

interval. Cronbach’s alpha test was employed to identify items with poor item-to-total correlation measure. After eliminating the items that failed in the test, retest, or alpha test phases, the remaining items were measured to have satisfactory construct reliability.

Participants were assigned to one of the four conditions based on the order of arrival in the lab. Participants were told that the purpose of the experiment was to test the usability of a newly developed self-tracking and self-monitoring application. After being told the purpose of the experiment, the participants were asked to don the self-tracking wearable device and were given several minutes to become familiar with it.

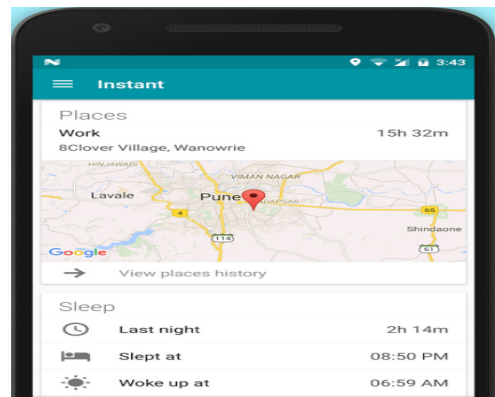


Fig. 3. Screenshot of the Quantified Self application (Android OS) using the non-comparative condition of feedback to participants

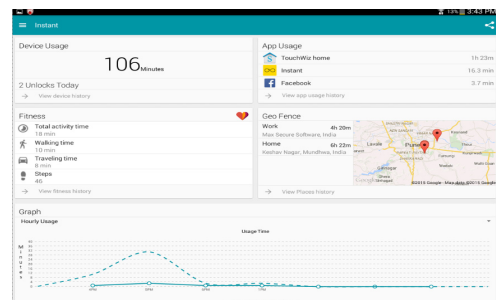


Fig. 4. Screenshot of the Quantified Self application (Android OS) using the comparative condition of feedback to participants

The participants were then asked to leave the lab, walk along a specified path for five minutes, and to use the self-tracking wearable device freely while walking. When the participants returned to the lab, the wearable device and the tablet computer were connected automatically via Bluetooth. Participants were then told to pay attention to a message on the tablet. The message included information concerning the participant's route and calorie consumption after walking, all of which was framed according to the treatment conditions. Lastly, the participants were asked to complete a survey questionnaire (administered on the tablet computer) that assessed health conservation tendencies and level of health consciousness.

3.6 Measurement

Health conservation tendency (Cronbach's $\alpha = .72$) was measured using five items that were adopted from Kim and Sundar[27] such as "I am willing to avoid something that harms my health," "I am willing to take preventive measures for my health," and "I am willing to cease partaking in behavior that threatens my bodily health."

Health consciousness ($\alpha = .79$) was assessed in this study in order to control for participant general consciousness of health condition. Health consciousness was measured using six items adopted from Hong[24] and Shin and Ahn[47] such as "I am concerned about my health all the time," "I notice how I feel physically as I go through the day," and "I take responsibility for the state of my health." Participants responded to these items using a 7-point Likert scale (1 = "strongly disagree," 7 = "strongly agree").

In research, perceived usefulness is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance[13]". The present study defined useful as "capable of being used advantageously." Within an

organizational context, user performance is generally reinforced by pay increases, promotions, bonuses, and other rewards[46]. Perceived usefulness of the experimental device was measured by several questions adapted from Davis: "Using in my health activity would enable me to accomplish tasks more quickly," "Using a wearable device and Quantified Self application would improve my health performance," "Using a wearable device and Quantified Self application would enhance my effectiveness in life," and "Using a wearable device and Quantified Self application would make it easier to be healthy." A Quantified Self system that is rated high in perceived usefulness indicates that a user gains understanding of their behavior from a quantitative perspective. Usefulness indicates that the user has a positive user-activity or user-data relationship. In addition, perceived ease of use refers to "the degree to which a person believes that using a particular system would be free of effort[13]". A particular Quantified Self application and personal informatics system that are perceived to be easier to use than another is more likely to be accepted by users[13].

IV. Results

The main goal of the present study was to gain a comprehensive understanding of users' perceptions of a Quantified Self personal informatics application. In order to achieve this goal, this study used an evidence-based analysis of the patterns of device notifications and their impacts on user task execution as reflected in user responses after the notifications.

The study conducted an analysis of experimental research data as detailed in the previous section. The results of the analysis can be divided into two sections: 1) health behavior change and 2) its effects due to the application interface design. First, the main

effects due to feedback type and visualization on health conservation are described (RQ.1). Subsequently, we present an analysis of the results of the interaction effect on comparison feedback type and visualization mode (RQ.2, RQ.3).

4.1 Main effects by feedback type

Two-way analysis of covariance (ANCOVA) was conducted to analyze the effects of feedback type and presentation modality on the dependent variable, followed by post hoc analyses using the Tukey-Kramer HSD test.

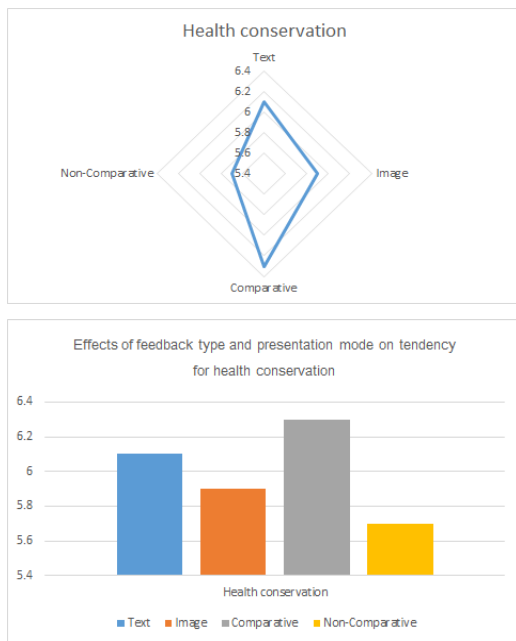


Fig. 5. Effects of feedback type and presentation mode on tendency for health conservation

The ANCOVA and subsequent post-hoc analyses indicated that participants who received comparative feedback (M = 6.26, SE = 1.1) reported a significantly greater tendency toward health conservation than those provided with non-comparative feedback (M = 5.84, SE = .11, F(1, 32) = 5.48, p < .05) (see [Fig. 5]).

In addition, presentation mode was found to have a marginally significant main effect on health conservation, such that participants who received the feedback in textual format (M = 6.18, SE = .11) showed a greater tendency toward health conservation than those who received identical feedback in image format (M = 5.62, SE = .11, F(1, 32) = 3.54, p = .06) (see [Fig. 5]). The two-way analyses of covariance (ANCOVA) also revealed that participant health consciousness was a significant predictor of level of tendency toward health conservation (F(1, 32) = 9.02, p < .01).

4.2 Interaction effects

Finally, two-way analysis of covariance (ANCOVA) identified an interaction effect between feedback type and presentation mode with regard to tendency for health conservation (F(1, 32) = 8.09, p < .01). For participants using the text mode, comparative feedback elicited a higher tendency toward health conservation than did non-comparative feedback. For participants in the image mode condition, however, health conservation tendency was not affected by the comparative vs. non-comparative difference (see [Fig. 6]).

4.3 Discussion

The use of self-monitoring technology and QS applications should theoretically result in healthy behavior changes; however, results from previous studies are somewhat inconsistent. A low level of engagement with self-tracking data often prevents users from gaining health-related benefits. Therefore, the present study investigated ways to engage users in the processes of self-monitoring and application use.

The results of the present study show that comparative feedback is more effective than non-comparative feedback with regard to promoting participants'

willingness to perform preventive healthcare measures. This is consistent with a prior study that revealed the positive effects of comparative feedback on energy-saving behavior, suggesting that the sense of comparison with others motivates users to positively change their behavior.

The findings also indicate that health feedback in textual format is more effective at increasing health preservation than the identical feedback in image format. This may be because health information tends to be objective and informative rather than entertaining and emotional. Given that textual information is typically regarded as more informative, analytic, and systematic than pictures, participants may have perceived textual feedback as more credible and trustworthy than the feedback sent in an image format.

Participants' health consciousness was found to play a significant role in health-related behavior: the higher the level of health consciousness, the greater the tendency for health preservation. This implies that program designers and health content providers should consider individual differences when implementing strategies for improving preventive healthcare results that involve the use of self-monitoring or self-tracking devices.

The interaction between feedback type and presentation mode also has practical implications. Our results indicate that comparative feedback elicited a higher tendency toward health preservation than did non-comparative feedback in participants who received messages in textual format (but not in those who received messages containing an image). When designing applications for low-end devices with limited features (e.g., slow CPU or low screen resolution), manufacturers and content providers should consider using comparative textual feedback, as these devices may not be capable of smoothly processing image or video information.

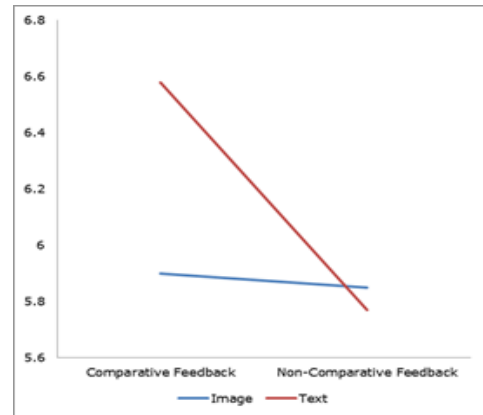


Fig. 6. Interaction between feedback type and presentation mode predicting tendency for health conservation

V. CONCLUSIONS

Use of self-monitoring technology and Quantified Self applications should theoretically result in healthy behavior change; however, previous studies' results are somewhat inconsistent across different devices. Furthermore, despite the increasing attention to the presentation mode versus comparative feedback framework, such framework has been rarely applied in the emerging Quantified Self or personal informatics.

A low level of engagement with self-tracking data often prevents users from gaining health-related benefits. Therefore, the present study investigated ways to engage users in the processes of self-monitoring and application use.

The present study demonstrates that comparative feedback is more effective than non-comparative feedback with regard to promoting participant willingness to perform preventive healthcare measures. This is consistent with a prior study that revealed the positive effects of comparative feedback on energy-saving behavior[36], suggesting that the sense of comparison with others motivates users to

positively change their behaviors.

The findings also indicate that health feedback in textual format is more effective at increasing health conservation than is the identical feedback in image format. This is may be because health information tends to convey objective and informative, rather than entertaining and emotional, content. Given that textual information is typically regarded as more informative, analytic, and systematic than pictures[26], participants may have perceived textual feedback as more credible and trustworthy than the feedback sent in an image format.

Participant level of health consciousness was found to play a significant role in health-related behavior: the higher was the level of health consciousness, the greater was the tendency for health conservation. This implies that program designers and health content providers should consider individual differences when implementing strategies for improving preventive healthcare results that involve the use of self-monitoring or self-tracking devices.

The interaction between feedback type and presentation mode also has practical implications. Our results indicate that comparative feedback elicited higher tendencies toward health conservation than did non-comparative feedback in participants who received the message in textual format (but not in those who received a message containing an image). When designing applications for low-end devices with limited features (e.g., slow CPU or low screen resolution), manufacturers and content providers should consider using comparative textual feedback as these devices may not be capable of smoothly processing image or video information.

The findings of this study is different from other research. All of these user experience inquiries will provide invaluable insights into developing the next generation of health informatics that will seamlessly

integrate into daily human lives while tracking, monitoring, recording, transferring, and utilizing various health and biometric data. This study makes its major contribution in providing the basis of understanding of the device, users, and interaction, and the subsequent attitude, behavioral intention, and satisfaction. In conclusion, following findings can be quickly summarized.

RQ1	How does the Quantified Self application help users promote healthy behavior change?
Answer	The use of Quantified Self application contributes to users promoted healthy behavioral change by increasing awareness and alert. Heuristic quality assessment shows that system interfaces could promote user health preservation. Participants' health consciousness was found to play a significant role in health-related behavior: the higher the level of health consciousness, the greater the tendency for health preservation.
Implication	This implies that program designers and health content providers should consider individual differences when implementing strategies for improving preventive healthcare results that involve the use of self-monitoring or self-tracking devices.
RQ2	How can we design persuasive performance feedback to enhance individual self-reflection and health conservation?
Answer	For health feedback in textual format is more effective at increasing health preservation than the identical feedback in image format. This may be because health information tends to be objective and informative rather than entertaining and emotional. Given that textual information is typically regarded as more informative, analytic, and systematic than pictures (Kim & Sundar, 2012), participants may have perceived textual feedback as more credible and trustworthy than the feedback sent in an image format. In addition, comparative feedback is more effective than non-comparative feedback with regard to promoting participants' willingness to perform preventive healthcare measures.
RQ3	What are the interface design implications for a Quantified Self application?
Answer	Effective integration of competition and presentation mode

VI. Limitations

This study has a few limitations, indicating the need for further research. First, a key limitation of the present study is that health conservation tendencies

may have been insufficiently tested. The tendency toward health conservation is an extremely long-term decision, and no single experience is likely to change a participant's perception about behavior. The short-term nature of this experiment may jeopardize the validity of the results and make it difficult to translate our findings into long-term behavioral modifications.

The present study investigated the effects of presentation mode and comparative feedback in a self-monitoring application as framed by user perceptions of a wearable device. As hypothesized, the results showed that users experienced a greater sense of health preservation when their activity was captured on their wearable device, which in turn, resulted in stronger feelings of health preservation. It may be worthwhile to investigate the long-term psychological effects of wearable devices or Quantified Self movement attachment because human-data relationships are shaped over time. In addition, it would be useful to examine the potential mediating effects of attachment on other variables such as perceived usefulness and ease of use of wearable devices. In addition, future research should examine variables pertaining to the content of the message itself (e.g., quality and credibility of the message) in order to explore how information is processed in a wearable and personal informatics context

VII. Research Implications and Future Research

The present research represents an effort to broaden the understanding of the implications of a Quantified Self application user perspective toward self-tracking. Although tracking tools are used to increase self-awareness and self-motivation, it is often difficult to provide direct engagement with

collected data. Therefore, in the design of applications that automatically track user activity, designers need to heighten the user experience. In order to accomplish this, the data sensing interface needs to require low mental workload and demonstrate high data accuracy. Moreover, activity cues are needed to increase engagement. For example, the Fitbit app is designed not only as a wearable sensor (accelerometer) to track physical activity, but also allows users to manually add food, mood, and water consumption and offers notifications to the user.

While the comparative feedback condition of our experiment compared participant performance against that of another participant, future research should consider comparing results with those of participants' friends or family members. This is because a sense of familiarity and intimacy may create stronger effects in the comparison intervention. In addition, future research should also explore the effects of feedback type and presentation mode on additional variables, such as credibility, trustworthiness, quality, usefulness, and intention to use. Furthermore, manipulation of feedback type (positive vs. negative) and investigation of additional presentation modes such as video and audio may offer additional insights into the role of wearable devices as tools for health support.

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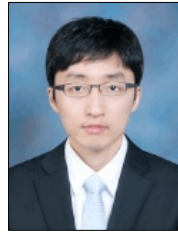
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