sustainability

MDPI

Article

# Using Traditional Chinese Medicine Ideas as a Mechanism to Engage People in Health Awareness

**Donglei Song [1], Yu Xia [1], Rusi Wang [2] and Hao Xu [1,3,4,5,*]**

1 College of Computer Science and Technology, Jilin University, Changchun 130012, China; dongleisong93@foxmail.com (D.S.); xiayu16@mails.jlu.edu.cn (Y.X.)
2 Mathematics School, Jilin University, Changchun 130012, China; wangrusiu@163.com
3 School of Management, Jilin University, Changchun 130012, China
4 Department of Computer Science and Technology, Zhuhai College of Jilin University, Zhuhai 519041, China
5 Symbol Computation and Knowledge Engineer of Ministry of Education, Jilin University, Changchun 130012, China
* Correspondence: xuhao@jlu.edu.cn

Received: 4 July 2018; Accepted: 30 July 2018; Published: 1 August 2018


**Abstract:** Improving health awareness is essential to health and healthcare sustainability. How to arouse attention to the health of people and encourage them to attend to healthcare progress so that we can reduce the costs of promoting healthcare by achieving more with less effort remains to be explored. In this paper, we provide a simplified health management app, called iTongue, with a basis in traditional Chinese medicine. People use iTongue to take pictures of their tongues to have a general idea of their health. We realize automated tongue image diagnosis using machine learning techniques to establish the relationship between the tongue image features and the cold or hot ZHENG (traditional Chinese medicine syndrome) in traditional Chinese medicine by learning through examples and assisting people to engage in health management. The results show that health management interaction based on traditional Chinese medicine has a positive influence on improving people's attention to their health, encouraging them to participate in health management activities and develop the habit of caring about their health over the long term. In the future, we could consider using this kind of traditional Chinese medicine idea as a means of publicity to engage people in healthcare and to assist healthcare sustainability development.

**Keywords:** health management; healthcare sustainability; traditional Chinese medicine; tongue diagnosis

## 1. Introduction

Health is one of the eternal issues for human beings and also the third sustainable development goal of the United Nations—"Ensure healthy lives and promote well-being for all at all ages" [1]. Health, as a universal right, is a basic resource for daily life and a social goal and political priority strategy shared by all countries. Nowadays, people's living conditions have been greatly improved, and the importance of health is widely recognized after the problems of food and clothing have been solved. A country's sustainable development is closely related to national health. Taking China as an example, the rise of the country is closely linked to the improvement in national health. The average life expectancy of the Chinese has rapidly increased, ranking among the highest in the same category of countries and regions and close to the level of developed countries [2]. In the 1970s, healthcare in China once covered almost all of the urban population and 80–90% of rural populations [3]. Chinese people's average age increased from 32 years old in 1950 to 69 years old in 1985 [2]. Research shows that a 20% growth of the national economy is achieved by reducing morbidity and mortality, with a

resulting increase in labor force [2]. If countries want to continue their methods of sustainable development, whether they can solve the problem of national health will become a very important issue. National health resources are one of the fundamental factors affecting countries' sustainable development. Almost every country has invested a great deal of human and financial resources in healthcare to ensure a healthy cycle of national health; in addition, countries have introduced a series of methods to help healthcare to be sustainable [4–7].

Besides offering high-quality service, controlling medical resources from a macro perspective as well as technological or organizational innovations, nations as participants also need to be taken seriously in order to achieve healthcare sustainability. Many researchers choose to motivate patients and change the relationship between patients and healthcare institutions to improve service quality and efficiency, which people achieve by participating in healthcare-related care work. Graffigna et al. proposed the patient health engagement model (PHE Model) to motivate patients in different healthcare settings and situations [8]. Individual health management (IHM) provides a multi-component lifestyle intervention program to increase physical activity, to reduce calorie intake and to practice both self- and stress-management [9]. Many companies offer individual health management with incentive management. For example, Integrated Health 21 encourages participants to adopt positive health behaviors by providing incentives to users [10]. In addition, there are many excellent health management apps, such as Keep [11]. Keep using its community as an incentive method to encourage users to share their experience. Many attempts are being made to encourage users to continue participating. However, most of the work takes place after people participate in the health-related process, such as when people want to improve their physical fitness by doing exercise or when people are already included in the healthcare process. How to engage people in healthcare-related work, such as health management, requires motivating them to participate rather than forcing them, and how to increase people's intrinsic motivation when they are careless about their health or have no awareness of health still remains to be explored.

Though people have demands regarding their healthcare, regimen and exercise, there is less motivation for people to continue the behaviors required for improving health. Compared with the great achievements in changing living conditions, there still needs to be more effort made to promote individual and societal progress by improving lifestyles. Many people are aware that lifestyle is one of the essential elements affecting health, but changing this is easier said than done. There should be a motivation to encourage people to manage their health. Especially in some developing countries, people pay less attention to health and have only a vague concept of health management. Some people even ignore the unhealthy signals bodies give under some circumstances [12,13]. In the meantime, high motivation is required in health-related care work and long-term participation is important for people [8]. Therefore, finding a method to encourage people to join primary health management, recognizing the importance of health, and obtaining the initial motivation will make potential contributions to the promotion of better healthcare in the future.

Traditional Chinese medicine (TCM) is easily accepted by people because it is close to life [14]. TCM applies different therapeutic methods to enhance the body's resistance to diseases and prevention. TCM performs diagnosis according to the information obtained from four diagnostic processes: that is, looking, listening and smelling, asking, and touching [15]. For thousands of years, Chinese medical practitioners have diagnosed the health status of patients' internal organs by inspecting the patterns of tongues. The changes of the tongue can objectively reflect the status of a disease, since the tongue shows a relationship with viscera. Then, it helps to differentiate syndromes, give proper treatment and herbs, and determine the prognosis of a disease [15]. Many foreign researchers are interested in the tongue diagnosis of TCM and have proposed many research methods to achieve an objective, standard, and intelligent tongue diagnosis. This research includes texture [16], color [17–19], shape [20,21], spectrum [17], and other tongue features which are extracted and analyzed. The scholars gradually discovered and integrated a set of significant features comprising a combination of geometric features (size, shape, etc.), cracks, and tongue moss [22]. Kanawong et al. categorized tongue images and

linked the cold or hot ZHENG (TCM syndrome) of tongue images with gastritis [15]. ZHENG in TCM, which is used to classify TCM disease, is the assemblage of disease symptoms and also the theoretical abstraction of the symptom profiles of individual patients [15].

The Shanghai Declaration on promoting health in the 2030 Agenda for Sustainable Development put forward China's declaration on the sustainable development of health: "Consider the growing importance and value of traditional medicine, which could contribute to improved health outcomes, including those in the sustainable development goals (SDGs) [23]" We improve the machine learning algorithm based on [15] and design the app iTongue as an engagement method, referring to the concept of healthcare in TCM to offer simple and easy access to health management. We chose the typical diagnostic process "look" in TCM to reflect users' health conditions by taking pictures of tongues. The iTongue app realizes intelligent tongue diagnosis and gives the ZHENG of users as feedback.

This work explored the effect of tongue diagnosis in TCM as an engaging method to improve health awareness and participation in health-related care work. We recorded users' performance and usage experience during the experiment. Then, we explored how this method influences users' health awareness and its potential contribution to healthcare management. Our results show that the iTongue, with the TCM idea, has positive effects on increasing frequency, being fun and taking initiative, and is a potential improvement in engaging people before they join the healthcare process. All of the findings provide viable and meaningful references to subsequent health incentives for users. This work could engage people in healthcare-related work, such as health management, increase people's intrinsic motivation and enhance healthcare publicity. We hope this work could contribute to the public's engagement in healthcare and help to promote healthcare sustainability development.

## 2. State of the Art

### *2.1. Patient Engagement*

Many researchers try to enhance the service efficiency and quality of healthcare by engaging patients and improving the relationship between patients and healthcare organizations. Graffinga et al. [8] have many works with patients on improving management approaches and the service delivery of healthcare systems. They focus on patients who have been involved in the healthcare process, engage with people such as chronic patients, and use an engagement mode to make healthcare systems become better attuned to the evolving demand of their clients. They use the conceptualization of consumer engagement to design the patient health engagement model and offer the decision-making process and goal management to engage with the patients. Graffinga et al. [8] think that encouraging patients to participant in healthcare is one of the key parts of high-quality healthcare services, especially in chronic conditions.

The individual health management (IHM) method focuses on improving people's personal responsibility, self-determination and health literacy [9]. The basic goal of IHM is to empower people to be their own health manager. IHM helps people to learn how to manage their health and optimize the body from the following aspects: physical activity, nutrition, self-efficacy and social support. IHM applies a blended learning concept in daily life and achieves behavioral change by offering personal contact to the IHM health coach, attending training sessions, and through telemonitoring. In addition, there are some methods in IHM to reduce attrition rates. IHM offers fellow intervention users, technical support, and training classes to engage with people from low socioeconomic backgrounds or the elderly, and an online community to give the chance to share experiences with other participants. A computerized reward system which collects compliance data from an individual participating in the health management program is designed to encourage participation in a health management program [4]. A reward will be given to an individual who is deemed compliant, if he is compliant, by comparing the compliance data with evaluation criteria.

In addition, there are many companies doing health-related work and providing incentive service during the health management process. Integrated Health 21 [10], a health management company,

offers incentive management in its provision of products and makes a point that the key to success of any wellness program is participation. The company will design and customize an incentive program to meet the needs of users' organizations and the motivation of their employees. There are also many excellent examples of personal daily life health management apps. For example, Keep [11], which was rated as one of the best apps of 2015 in the Apple app store in China, integrates fitness teaching, running, cycling, social context, fitness and diet instruction and equipment purchase. This app uses the idea of internet fitness and combines personal health with smartphones. Several methods including daily bonus, self-evaluation, and personalized fitness plan recommendation have been used in the app to engage users. The community of Keep encourages users to share their experience and become a star of their community.

### *2.2. Tongue Diagnosis in Health*

Many works have been proposed regarding tongue diagnosis to verify its validity and relationship with Western medicinal diagnosis [15]. In the 1980s, through the efforts of the University of Science and Technology of China and Anhui University of Chinese Medicine [24], researchers explored the colored tongue images using computer graphics technology and found that the shape, color and grayscale had a high weight in diagnosing tongues. The objectification and standardization of early tongue diagnosis were limited to the study of computer hardware and algorithm techniques. However, the study of computer graphics techniques laid a good foundation for the development of subsequent computer tongue diagnosis.

Xu et al. from the Shanghai University of Traditional Chinese Medicine [14] have devoted many years to verifying a combined application of computer technology and tongue diagnosis from different aspects. They classified the tongue images by applying a grayscale differential algorithm to describe the texture of the body and coating according to contrast (CON), angle second moments (ASM), entropy (ENT), and mean [14]. They designed a computer analysis and identification method of tongue moss color and indicated the feasibility of digitalized tongue diagnosis [14].

Kanawong et al. [15] achieved positive results using machine-learning techniques to classify the tongue images and establish the relationship between the tongue image features and ZHENG by learning through examples. They design an automated tongue-image diagnosis system and extracted objective features from the tongue images of clinical patients. Then, they analyzed the relationship between tongue images corresponding to cold or hot ZHENG data and gastritis prognoses obtained from clinical practitioners. A novel color-space-based feature set, which can be extracted from tongues, has been proposed in this work.

## 3. iTongue App

We validate our proposed solution through an app, iTongue, which uses our improved machine learning algorithm based on Kanawong et al.'s previous work [15]. The algorithm improves the accuracy of classification and is able to classify tongue images into three types: cold ZHENG, hot ZHENG and normal [25]. In the test phase, the correct classification rate of the trained sample of the tongue image data provided by Shanghai University of Traditional Chinese Medicine was as high as 99.8%. For the test sample, the classification accuracy rate reached 94.4% [25]. iTongue is implemented to provide the users with a diagnosis of their tongue images. The interface of the iTongue app is shown in Figure 1.

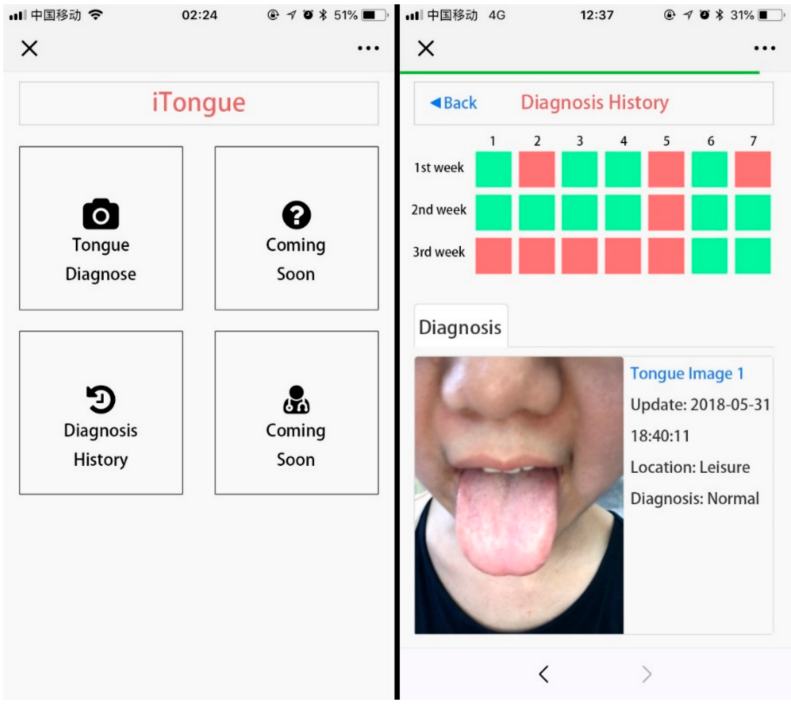


**Figure 1.** Welcome page and history page of the iTongue app.

ITongue provides two functions for the users:

*Taking pictures of the tongue:* iTongue is designed to collect data from the tongue by taking pictures. First, after receiving a picture sent by the user, we need to determine whether the picture is a tongue. In order to ensure that the tongue can effectively reflect the body's condition, we choose to exclude factors other than the tongue itself. We use the tongue image segmentation method proposed by Kanawong et al. in previous work [15] to reserve the tongue itself and remove redundant information such as the lips and face. The procedure of the tongue image segmentation is shown in Figure 2. According to the segmentation algorithm, we perform a boundary check to obtain the outline of the tongue image in the center, as shown in Figure 2b. Then the outline image is matched with the original image (Figure 2a). After the Boolean operation, the single tongue image required in this paper is obtained, as shown in Figure 2c.

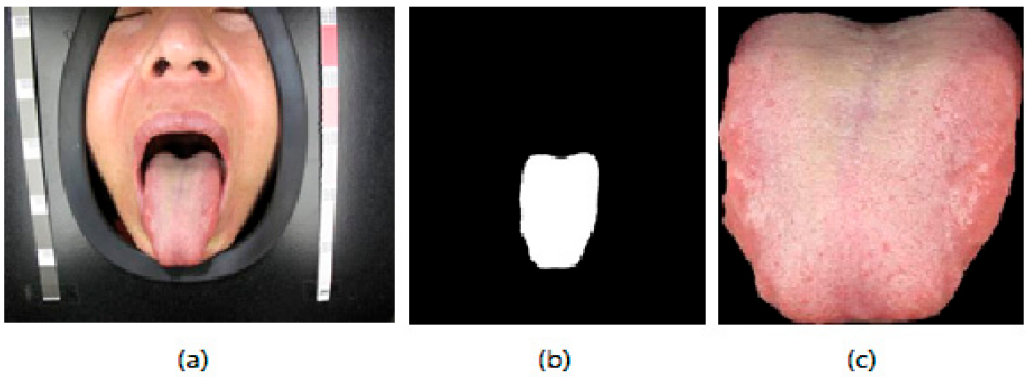


**Figure 2.** Tongue image segmentation.

The results for ZHENG are provided by an improved machine learning algorithm after the app confirms that the picture is a tongue. According to the tongue images, the result for ZHENG will

be given to the users as a feedback to show whether users are in the cold ZHENG, hot ZHENG or normal group.

*View diagnosis history:* iTongue provides a timeline to show previous results. Users will have some basic knowledge of their health conditions. There is some evidence that users perform better when using personal digital assistants compared with paper records [26]. The results are shown by the day in Figure 1. Green refers to normal, red refers to hot and blue refers to cold. The table shows the latest diagnosis of that day.

## 4. Experimental Design Overview

In order to verify the effect of improving the general public's health awareness and participation in health management by using iTongue, 40 users took part in this experiment. All the users have been divided into two groups randomly with a similar sex ratio (11 males and 9 females). The experiment lasted for three weeks (21 days). The experimental group used iTongue to manage their health during the experiment period and received questionnaires before and after the experiment. The control group received the same questionnaires as the experiment group without using iTongue.

Before the experiment began, a questionnaire was given to all 40 participants to obtain their basic understanding of their health. The first part of the questionnaire mainly collected the participants' understanding and trust in TCM, and the second part collected participants' knowledge of their health. For example, the questions about the knowledge of their health included these factors: the degree of attention to their own health, understanding of their own level of health, awareness of the level of health management, and attitude to maintaining their own health in daily life. Then, 20 participants in the experimental group began to use the iTongue app on their mobile phones for three weeks. They mainly used the tongue diagnosis function and history viewing function. We recommended all participants to use iTongue at least once a day, but the actual usage time was determined by themselves. For example, they could choose to use iTongue three times a day or not to use it. During the experiment, we collected data about the use of iTongue, such as the login status, the use of each function, the geographic location (i.e., home, work and leisure) when using the app. The 20 other participants in the control group did not use iTongue. The control group only received one piece of health information each week during the experiment without any interaction. After the experiment, all 40 participants received an end questionnaire with the same questions about health as the begin questionnaire. The experimental group had some new questions about iTongue evaluation. Two questionnaires compared the cognitive changes of the participants before and after the experiment.

## 5. Results

Initially, we analyzed the iTongue usage data of the experimental group to check if the tongue diagnosis method in TCM had a positive influence on their daily activities. An analysis of daily usage of the iTongue app is shown in Figure 3. Figure 3 shows the average number of using times and the participants using iTongue in each day. The average number of daily using was 13 times, and the average number of daily participants was 10.52. Half of the 20 participants accumulatively used iTongue for more than two weeks during the 21-day experiment period, and 13 participants used iTongue for more than one week. Over 50% of participants insisted on reaching a 66.7% use rate. These participants basically kept an average of 1.02 daily usage times. The maximum number of use in one day is three times a day. Two participants quit the process after a single use. There are four participants who used the app more than once per day. The participants who exceeded the expected use accounted for 20%. Usage of the four participants who used the app more than expected is shown in Table 1. Observing the usage during the experiment period, we could find that, although there is a decrease in the number of active participants or the number using iTongue, it is a periodic fluctuation. We could find that, almost every six days, the amount of usage decays from its peak and rises slightly on the seventh day, and then decays again in one week. In this case, we speculate that the period of participating in health-related care work is close to the natural week. The participation of users will

naturally attenuate within each week and receive a higher degree of enthusiasm in the beginning of new weeks. We consider that, in future health-related designs, we could make a division of the time into weeks and complete a small-period incentive plan.

Although there is an inevitable loss of users, which is very common in using products, more than 50% of users were retained in our iTongue app. That indicates that our app has a positive effect on users' daily health care behavior. Some of these users who are sensitive to our application may consider using our similar method to encourage them in future engagement design. We also found that the participant who did not agree with TCM (Participant 5 in experiment group) gave up after using iTongue once. We consider that it is easier for people with non-negative attitudes to TCM to receive incentives from our methods. Some of the lost users may not be sensitive to this incentive. This incentive effect is manifested in the fact that it is more likely to encourage participation in health-related care work such as health management. We need to combine other incentives so that lost users are willing to participate in health-related care work.

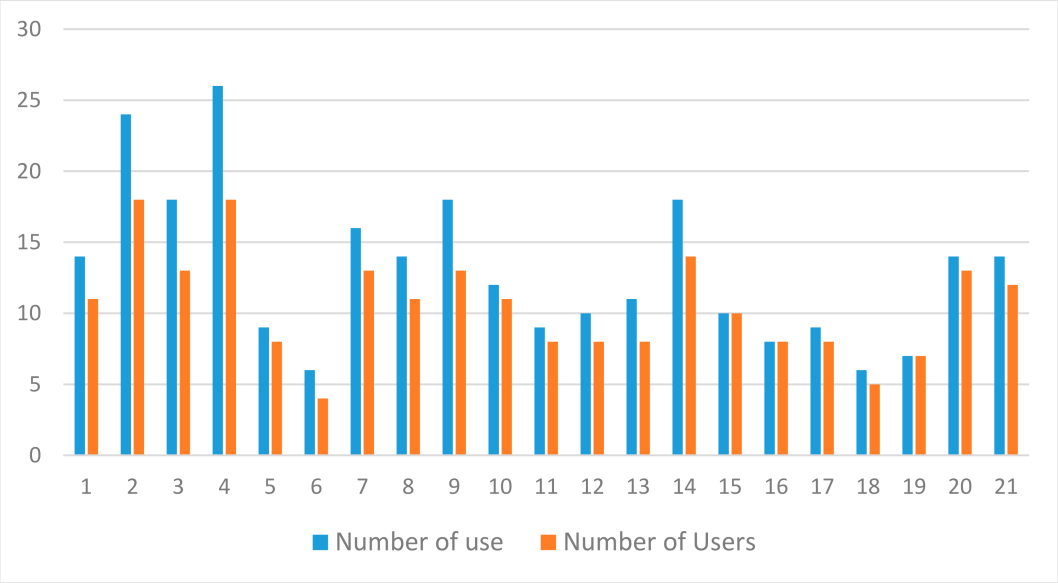


**Figure 3.** Usage of iTongue.

**Table 1.** Usage of four participants who used the app more than once per day.

| Contents | Participants | | | |
|---|---|---|---|---|
| | **Participant 1** | **Participant 2** | **Participant 7** | **Participant 19** |
| Mean value of number of use | 1.81 | 1.10 | 1.19 | 1.14 |
| Total number of using days | 21 | 19 | 20 | 19 |
| Using days which more than twice a day | 13 | 4 | 5 | 5 |

The usage locations were analyzed to show the preference of using environment. Figure 4 shows the usage locations of iTongue. About 83% usage happened at home, 11% at work place and 6% at leisure place. We consider that people feel relax when they are not involved in hard work or doing entertainment activities. We could infer that, in health-related incentives, the home could be considered as a possible place to have a better effect on users such as encouraging them to join in the health-related activities.

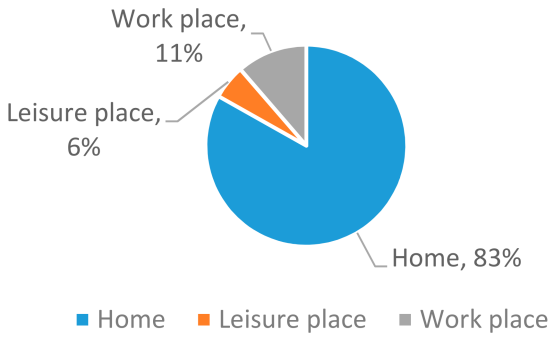


**Figure 4.** Usage locations of iTongue.

We then analyzed the other operations during the usage of iTongue. The average number of users using the history function each day is 5.67. Over 95% of the participants viewed their history at least once to have a knowledge of their own tongue condition. We analyzed all the activities that view the history and perform tongue diagnosis. The operations whose time differences were within 5 minutes accounted for 50% of the total viewing history operations. We consider intuitive feedback on the previous results, which will have a positive impact on the participants' enthusiasm. It helps participants to have an overall understanding of their health condition before and after using the tongue diagnosis function. Feedback as an incentive element interacts directly with the user through a graphical approach, which has a positive effect on maintaining the user's long-term effectiveness.

The results of the questionnaire showed the attitude of participants toward the awareness of their health and the use of iTongue based on tongue diagnosis method. A paired *t*-test was conducted to compare four stages of two groups. In addition, Cronbach's $\alpha$ analysis was calculated to the health-related part (3 items), as shown in Table 2. All three health-related questions in these four stages were the same. Most of the questionnaires have acceptable values of alpha ($\alpha > 0.7$) which indicate high internal consistency of the rating scale [27]. First, we compare the experimental group and control group before the experiment started about their attitude to TCM and their understanding of their health and health management. The result shows that there was no significant difference between the experimental group and control group ($p = 0.6444 > 0.05$) before the experiment. We could think that participants' attitudes to TCM and their understanding of their health and health management before the experiment has no influence on the final results of the questionnaires after the experiment.

**Table 2.** Results of questionnaire about health awareness. The $\alpha$ indicates reliability of health-related part. * indicates cells with $p < 0.05$.

| Group | | *p*-Value | |
|---|---|---|---|
| | | **Experiment Group** | **Control Group** |
| | | **Before ($\alpha = 0.74$)** | **After ($\alpha = 0.71$)** |
| **Control Group** | Before ($\alpha = 0.78$) | 0.64 | 0.55 |
| **Experiment Group** | After ($\alpha = 0.62$) | 0.04 * | 0.02 * |

Then, we analyzed the questionnaire data of the experimental group. Through the paired *t*-test, we found that the results after the experiment were significantly better than the results before the experiment ($p = 0.04452 < 0.05$). On the question related to how much the participants know about their health, answers moved to the positive options (before: mean = 3, median = 3; after: mean = 3.6, median = 4). On the question related to the attitude to keeping healthy in daily life, answers moved to the positive options (before: mean = 3.9, median = 4; after: mean = 4.25, median = 4). On the question

related to the attitude towards joining health management, answers moved to the positive options (before: mean = 3.95, median = 4; after: mean = 4, median = 4). The questions about user experience of iTongue also showed positive results. All 20 participants chose the positive options and showed their willingness to continue using iTongue in future.

There is no significant difference between the questionnaires before and after the experiment about health awareness in the control group ($p = 0.5453 > 0.05$). However, in the after-experiment questionnaire, the experimental group showed better results than the control group ($p = 0.0231 < 0.05$). On the question related to how much the participants know about their health, answers moved to the positive options (control: mean = 3.15, median = 3; experimental: mean = 3.6, median = 4). On the question related to the attitude to keeping healthy in daily life, answers moved to the positive options (before: mean = 3.75, median = 4; after: mean = 4.25, median = 4). On the question related to the attitude towards joining health management, answers moved to the positive options (before: mean = 4, median = 4; after: mean = 4, median = 4). The experimental group performed better in all three questions about health awareness.

After the experiment, we made a follow-up survey for one week of the 10 participants in the experimental group who used iTongue for more than two weeks during the experiment. There are six participants who have kept a better pattern of life than before in most of the days in terms of their sleep time (i.e., 10:00 p.m.–1:00 a.m.), wake-up time (i.e., 6:00 a.m.–9:00 a.m.), nutrition of meals, and physical exercise. Three participants claimed that they failed to go to sleep before 1:00 a.m. because of the heavy work. One participant said that she liked to sleep late and wake up late, and it was hard for her to change it. All 10 participants reported that they pay more attention to their daily health condition after using iTongue instead of just doing a medical examination after a long time. Some time management tools could be considered to add into the health-related work to help these participants. In addition, the healthcare organizations and government should work together to standardize the working hours and ensure enough break time for people.

## 6. Discussion

Our results showed that iTongue has a positive influence on users. This conclusion is derived from the usage of iTongue and the questionnaires. Most of the participants kept up regular use of iTongue app. In the questionnaire, the participants in the experimental group who used iTongue have more positive improvement in their awareness of their health and higher user satisfaction compared to the control group and the experimental group before the experiment. Our findings can be possibly applied in health-related work design to achieve more effective results.

In our exploratory experiment, we used the method that combined TCM and machine learning algorithm to help people to improve their health awareness. Rather than the high ZHENG classification accuracy of the algorithm, in this paper, we are more concerned about the application context of this kind of smart diagnosis in the non-medical environment, specifically in normal life. ITongue showed a possible context to combine the artificial intelligence (AI) technology with daily health. It provided people with an easily obtained medical AI technology—smart tongue diagnosis—to help people have knowledge of their health in daily lives instead of going to the hospital every day to know about their bodies. We got positive feedback from the participants during the experiment. It suggested that medical AI technology could be designed to bring convenience and motivation to the people in the non-medical environment.

The interaction method between tongues and smartphones also provide valuable and effective ideas to the health-related work design in the future. Using smartphones to take a picture of tongues is just as easy as taking a selfie. Participants kept a good usage of iTongue during the experiment and reported their satisfaction with the app. This way of interacting has a low cost because of the widely used smartphones and simple operation of taking tongues' pictures. Therefore, we recommend that designers could consider this interaction method when doing mass health mobilization such as encouraging people to do health management.

The idea of iTongue could also be considered to provide pre-training and pre-engagement before people's formal involvement in the health-related work. People are more likely to participate in health-related work actively with a high health awareness. For example, during the questionnaire and interview for user experience, over half of the students (75%) thought that iTongue helped them to learn about their health and attached more importance to it:

> "When I discovered that I had been diagnosed as hot ZHENG for three days in a row, I had some concerns about my body. I didn't expect that I caught a cold the next day. I think the results of tongue diagnosis from the previous days were warning me but I ignored it. I will pay more attention to my physical changes and prevent diseases in the future." (Participant 12)

There are some limitations of our work. Other factors of participants might play a role in determining performance and perceptions of health, such as their countries and regions of origin, cultural background, understanding of TCM and age. More experiments will be considered according to other factors.

## 7. Conclusions

This work explores tongue diagnosis as an engagement method to improve health awareness and participation in health management activities. The results showed that the use of a TCM idea would increase the potential value of people's enthusiasm before they enter health-related care work and could help healthcare organizations to achieve the effect of healthcare publicity. We have found that using the tongue image diagnosis and treatment of TCM to provide users with a ZHENG score of their own physical condition had positive effects on increasing participation frequency, being fun, and participation initiative. People's acceptance of iTongue is high, and the feedback for user experience is positive. At the same time, during the experiment, we discovered the users' weekly fluctuations and the attention period for their own health in the daily time period. The location preference to do health-related work is home. The above findings all provide viable and meaningful references for subsequent health incentives for users. This work could engage people in healthcare-related work, such as health management, motivate them to participate, and increase people's intrinsic motivation when they are careless about their health or have no awareness of health. We hope this work could contribute to the public's engagement in healthcare and help to promote healthcare sustainability development. In future work, we will consider more factors, such as age, educational background, and cultural background to explore whether there are any other influences on the motivation for using iTongue's tongue diagnosis.

**Author Contributions:** All authors have contributed to the intellectual content of this paper. D.S. designed and conducted the research and wrote the manuscript. Y.X. designed the program and analyzed the data and wrote the manuscript. R.W. analyzed the data and wrote the manuscript. H.X. conducted the program, designed the research and helped revise the manuscript.

**Funding:** This research was funded by the [Development Project of Jilin Province of China] grant number [20160414009GH, 20170203002GX, 20170101006JC, 20160204022GX], the [National Natural Science Foundation of China] grant number [61472159, 71620107001, 71232011], the [Jilin Provincial Key Laboratory of Big Date Intelligent Computing] grant number [20180622002JC]. The Premier-Discipline Enhancement Scheme supported by Zhuhai Government and Premier Key-Discipline Enhancement Scheme supported Guangdong Government Funds.

**Acknowledgments:** We thank Dong Xu from University of Missouri-Columbia, US for his technical support, valuable comments and constructive suggestions.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References


1. World Health Organization. Goal 3: Ensure Healthy Lives and Promote Well-Being for All at All Ages. United Nations New York. Available online: http://www.webcitation.org/717dsnGUK (accessed on 23 July 2018).
2. National Health Commission of the People's Republic of China. *Annual Statistics of China's Health Care*; People's Medical Publishing House: Beijing, China, 1987; ISBN 140-485-408.
3. Zhang, Z.; Fang, L.; Bloom, G. The Rural Health Protection System in ChinaDevelopment and Institutional Arrangements of the New Rural Cooperative Medical Scheme and Medical Assistance. In *Health Policy in and for China*; Lin, V., Yan, G., Legge, D., Eds.; Peking University Medical Press: Beijing, China, 2010; ISBN 978-781-116-699-6.
4. Brown, S.J. Computerized Reward System for Encouraging Participation in a Health Management Program. U.S. Patent 6,151,586, 21 November 2000.
5. Rosenberg-Yunger, Z.R.; Daar, A.S.; Singer, P.A.; Martin, D.K. Healthcare sustainability and the challenges of innovation to biopharmaceuticals in canada. *Health Policy* **2008**, *87*, 359–368. [CrossRef] [PubMed]
6. Capolongo, S.; Bottero, M.C.; Lettieri, E.; Buffoli, M.; Bellagarda, A.; Birocchi, M.; Cavagliato, E.; Dervishaj, A.; di Noia, M.; Gherardi, G. Healthcare sustainability challenge. In *Improving Sustainability during Hospital Design and Operation*; Springer: Berlin, Germany, 2015; pp. 1–9.
7. Barile, S.; Saviano, M.; Polese, F. Information asymmetry and co-creation in health care services. *Australas. Mark. J.* **2014**, *22*, 205–217. [CrossRef]
8. Graffigna, G.; Barello, S.; Triberti, S. *Patient Engagement: A Consumer-Centered Model to Innovate Healthcare*; Walter de Gruyter GmbH & Co KG: Berlin, Germany, 2016; ISBN 978-311-045-243-3.
9. Melchart, D.; Eustachi, A.; Wellenhofer-Li, Y.; Doerfler, W.; Bohnes, E. Individual health management-a comprehensive lifestyle counselling programme for health promotion, disease prevention and patient education. *Complement. Med. Res.* **2016**, *23*, 30–35. [CrossRef] [PubMed]
10. Integrated Health 21. Available online: http://www.webcitation.org/717bLZDxj (accessed on 23 July 2018).
11. Keep. Available online: http://www.webcitation.org/717dD1HUq (accessed on 23 July 2018).
12. Saw, S.-M.; Hong, C.-Y.; Lee, J.; Wong, M.-L.; Chan, M.-F.; Cheng, A.; Leong, K.-H. Awareness and health beliefs of women towards osteoporosis. *Osteoporos. Int.* **2003**, *14*, 595–601. [CrossRef] [PubMed]
13. Olusile, A. Improving low awareness and inadequate access to oral health care in nigeria: The role of dentists, the government & non-governmental agencies. *Niger. Med. J.* **2010**, *51*, 134–136.
14. Xu, J.; Sun, Y.; Zhang, Z. Analysis and discrimination of tongue texture characteristics by difference statistics. *J. Shanghai Univ. Tradit. Chin. Med.* **2003**, *17*, 55–58.
15. Kanawong, R.; Obafemi-Ajayi, T.; Ma, T.; Xu, D.; Li, S.; Duan, Y. Automated tongue feature extraction for zheng classification in traditional chinese medicine. *Evid.-Based Complement. Altern. Med.* **2012**, *2012*, 912852. [CrossRef] [PubMed]
16. Chiu, C.; Lin, H.; Lin, S. A structural texture recognition approach for medical diagnosis through tongue. *Biomed. Eng. Appl. Basis Commun.* **1995**, *7*, 143–148.
17. Liu, Z.; Yan, J.-Q.; Zhang, D.; Li, Q.-L. Automated tongue segmentation in hyperspectral images for medicine. *Appl. Opt.* **2007**, *46*, 8328–8334. [CrossRef] [PubMed]
18. Wang, Y.-G.; Yang, J.; Zhou, Y.; Wang, Y.-Z. Region partition and feature matching based color recognition of tongue image. *Pattern Recognit. Lett.* **2007**, *28*, 11–19. [CrossRef]
19. Li, C.H.; Yuen, P.C. Tongue image matching using color content. *Pattern Recognit.* **2002**, *35*, 407–419. [CrossRef]
20. Pang, B.; Zhang, D.; Wang, K. The bi-elliptical deformable contour and its application to automated tongue segmentation in chinese medicine. *IEEE Trans. Med. Imaging* **2005**, *24*, 946–956. [CrossRef] [PubMed]
21. Obafemi-Ajayi, T.; Kanawong, R.; Xu, D.; Li, S.; Duan, Y. Features for automated tongue image shape classification. In Proceedings of the IEEE International Conference on Bioinformatics and Biomedicine Workshops, Philadelphia, PA, USA, October 2012; pp. 273–279.
22. Chiu, C.-C. A novel approach based on computerized image analysis for traditional chinese medical diagnosis of the tongue. *Comput. Methods Programs Biomed.* **2000**, *61*, 77–89. [CrossRef]
23. Organization, W.H. Shanghai declaration on promoting health in the 2030 agenda for sustainable development. *Health Promot. Int.* **2017**, *32*, 7–8. [CrossRef] [PubMed]

24. Liyou, S.; Zhao, C.; Fengsheng, G.; Huchen, X.; Wenjie, X. Discussion on the objectification research of tongue diagnosis using computer image recognition technology. *J. Anhui Tradit. Chin. Med. Coll.* **1986**, *5*, 5–7.
25. Guozheng, L. Research on Application of Traditional Chinese Medicine Tongue Images Classification Based on CNN. Master's Thesis, Jilin University, Jilin, China, 23 June 2018.
26. Burke, L.E.; Styn, M.A.; Glanz, K.; Ewing, L.J.; Elci, O.U.; Conroy, M.B.; Sereika, S.M.; Acharya, S.D.; Music, E.; Keating, A.L. Smart trial: A randomized clinical trial of self-monitoring in behavioral weight management-design and baseline findings. *Contemp. Clin. Trials* **2009**, *30*, 540–551. [CrossRef] [PubMed]
27. DeVellis, R.F. Applied social research methods series. In *Scale Development: Theory and Applications*; Sage Publications, Inc.: Thousand Oaks, CA, USA, 1991; Volume 26, ISBN 978-141-298-044-9.