Designing Intelligent Self-Checkup Based Technologies for Everyday Healthy Living

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Abstract

Recent years have seen increasing interest in health promotion or disease prevention, rather than disease treatment/management, as a more cost-effective approach towards healthcare. Technologies designed to help build healthy habits, or lifestyle technologies, have important roles to play in that respect. However, so far, they are mainly explored without considering individual health statuses, which may lead to people's excessive pursuit of quantified goals and cause negative health outcomes. In addition, while AI-powered health checkup technologies have become available for consumers to assess health on their own, they are mainly disease-oriented, and their potential for preventive health – everyday health assessment and early interventions through lifestyle changes – has been largely under-explored. This paper attempts to combine intelligent self-checkup and personalized lifestyle technologies so as to provide suggestions based on personal health status, as a potentially more effective approach to support preventive health in everyday life, or **everyday healthy living** as we call it in this paper. In particular, we present the iterative design process of a mobile application which supports

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AI-powered everyday health assessment based on face examination and adaptive inquiry, and provides personalized and adaptive lifestyle advice. Design improvements were made based on the first pilot study, and a 4-week field trial of the final design prototype reveals a number of design implications for intelligent health technologies to better support everyday healthy living.

Keywords: Everyday Health, Healthy Living, Self-Checkup, Lifestyle Technologies, Personalized, Traditional Chinese Medicine

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1. Introduction

Beyond traditional disease treatment/management, detection and intervention before a disease worsens, or even appears, is a global trend. This is known as preventive health (Kasl and Cobb, 1966; Rosenstock, 1974; Moorman and Matulich, 1993), which has been shown to substantially reduce the risk of chronic diseases and improve quality of life (Levine et al., 2019) in a more cost-effective manner (Rasmussen et al., 2007). Traditionally, preventive health centers around people going to healthcare providers for regular checkups and screening tests to see if any health issues are emerging and to catch them in time. While seemingly promising, affordability and accessibility (Riley and Riley, 2012) remain primary barriers for vulnerable populations, causing increased disparities in healthcare (Morrison et al., 2012).

Digital health technologies hold the potential to bring preventive health into everyday lives in a more accessible and affordable manner. In particular, the use of self-tracking and AI technologies can help assess an individual's health status and provide personalized suggestions for more effective health maintenance and promotion. For instance, we can leverage consumer-facing self-checkup technologies (Millenson et al., 2018) to bring attention to health issues before a disease occurs and encourage lifestyle changes (Kerner and Goodyear, 2017) as early interventions. We call this approach **everyday healthy living**, as distinct from traditional preventive health.

Existing health technologies, however, still have a long way to go to realize such potential. Of particular relevance are lifestyle technologies, especially those designed to help build healthy habits, often based on self-tracking data (Lentferink et al., 2017; Adams et al., 2013; Rabbi et al., 2015b) on particular health behaviors (e.g., appropriate eating, physical activity) (Rabbi et al., 2015b; Adams et al., 2013; Lin et al., 2006). While these technologies promise to promote health, so far they have been mainly quantitative-measure-oriented, also known as the "quantified self" (Lupton, 2016). Without the consideration of individual health statuses, they may lead to an excessive pursuit of quantified goals, resulting in negative health outcomes, such as over-exercising (El Ghoch et al., 2016; Peñas-Lledó et al., 2002; Kellmann et al., 2018) or over-dieting (Rich et al., 2020). While AI-powered self-checkup technologies have become increasingly available for consumers to conduct self-diagnosis in everyday settings, a.k.a., consumer-facing self checkup tools, they are still mainly disease-oriented (Tentori et al., 2012), limited to providing diagnostic results or assisting with triage. As such, this is a missed opportunity to provide personalized lifestyle suggestions based on health assessments during a period in which early interventions, such as lifestyle changes, rather than medical treatments, are sufficient.

In this paper, we explore whether combining intelligent self-checkups and personalized lifestyle technologies could offset their individual limitations and unleash the great potential of digital health technologies to support everyday healthy living. In this study, we chose Traditional Chinese Medicine (TCM) as our knowledge base because it emphasizes the prevention of diseases and offers rich practical suggestions for people to cultivate health through everyday activities. Specifically, our AI-powered self-checkup technology is based on TCM diagnostic methods and assesses a user's health status in terms of balanced (healthy) and unbalanced (might not be ill yet) body constitutions[1], and then provides corresponding lifestyle suggestions. As such, compared to common lifestyle technologies which focus on more general health suggestions, our design takes individual differences and health statuses into consideration, providing suggestions in a more personalized and adaptive way. Although the exploration is based on TCM, a medical system primarily developed and practiced in Asia, and the prototype itself mainly targets the Asian population accordingly, the design implications derived from our study can contribute to the larger strand of research on intelligent technologies for everyday healthy living, e.g., providing lifestyle suggestions based on Heart Rate Variability (HRV) detection and analysis (Cherkas et al., 2015).

We conducted a three-year-long, iterative design study of how such intelligent technologies might be used and shall be designed for everyday healthy living. As an extension to our early work (Ding et al., 2019), which uncov-

[1]A concept in Traditional Chinese Medicine to describe the individual's health condition, which treats the body as a whole instead of focusing on specific areas of the body

ered many usability issues and design challenges for such technologies to be integrated in everyday settings, this paper focuses on incorporating design implications developed from previous work into a new chatbot-based design prototype, featuring adaptability, flexibility, and transparency. We then conducted a 4-week field study (N=13) of the new prototype, and gained a better understanding of how such design combining self-checkup and lifestyle technologies might be used, and how users might engage and interact with it in everyday life. In particular, our contributions are threefold:

- A novel approach for everyday healthy living, combining intelligent self-checkup and lifestyle technologies.
- A functional, interactive system that provides AI-powered health checkups, and personalized and adaptive health suggestions based on TCM.
- Understandings of how such an intelligent technology might be used and shall be designed for everyday healthy living.

2. Related Work

In this section, we review related works on everyday health technologies, first on AI-powered self-checkup tools, then on lifestyle technologies for healthy living.

2.1. AI-powered Self-checkup Tools

Recently, due to advances in mobile health technologies and the increasing availability of smartphones, lay people have had new opportunities to detect health issues or monitor their health status in the everyday context. In particular, AI-powered self-checkup tools, or consumer-facing digital symptom checkers, can solicit and analyze users' descriptions of their symptoms in order to provide a potential diagnosis or point them to the appropriate care setting (Semigran et al., 2015). Developers of AI-powered symptom checkers have promised various benefits, such as providing quality diagnosis (Copestake, 2018) and decreasing the risks of life-threatening cases (Semigran et al., 2015) and unnecessary visits and tests (Kao and Liebovitz, 2017).

The more traditional self-diagnosis method involves collecting and analyzing users' self-reported data on their symptoms and feelings along with their basic information (Divya et al., 2018), which has been vastly explored in academia (Divya et al., 2018; Kao et al., 2018) and implemented in many popular commercial symptom checkers (e.g., Buoy Health (Buoy Health Inc., n.d.), Isabel (Isabel Healthcare, n.d.) and Babylon (Babylon Health, n.d.)). However, the health information provided by users through this inquiry process is often inadequate to make a diagnosis (Kao et al., 2018). In addition, a patient's personal feelings and perceptions of their symptoms may not reflect their real health status (Ding et al., 2019). This lack of reliable, well-rounded information can result in an inaccurate diagnosis.

In recent years, the built-in sensors of smartphones have been explored to support more accurate and convenient self-diagnosis. These sensors, including accelerometers and cameras, can collect rich biometric information, possibly leading to a more accurate diagnosis than the sole use of self-reported data as mentioned above. For the potential diagnosis of diseases, a couple of examples include recording coughing sounds to detect COVID-19 infections (Imran et al., 2020), taking oral photos to self-examine common oral conditions (Liang et al., 2020), and taking eye images to detect cataracts (Rana and Galib, 2017; Diethei and Schöning, 2018). For the continuous monitoring of diseases, the unobtrusive and always-available nature of mobile phones enables a convenient, cost-effective measurement of blood pressure (Wang et al., 2018a) and bilirubin (Mariakakis et al., 2017).

At the moment, existing self-checkup tools are primarily designed for the diagnosis of specific diseases, and assisting with triage (e.g., help users decide whether/where they should seek medical care), not for the purpose of everyday healthy living as what we are concerned here.

2.2. Lifestyle Technologies

Most healthy-living-related technologies are those we call lifestyle technologies. By allowing people to track activities and personal health data, sometimes integrated with persuasive techniques such as goal setting (Lin et al., 2006; Munson and Consolvo, 2012; Adams et al., 2013; Bickmore et al., 2013) and social comparisons (Pina et al., 2017), these technologies aim to enhance people's awareness of their lifestyles and persuade them to adopt healthy habits, e.g., encouraging physical activity (Adams et al., 2013; Consolvo et al., 2006) and nutritional intake (Bickmore et al., 2013; Cordeiro et al., 2015). With easier access to various sources of data about people's health and wellbeing, researchers have also explored combining data from different sources to provide people with meaningful insights into the long-term impact of their patterns of daily life and support self-reflection on various aspects of lifestyle choices. The Health Mashups system (Bentley et al., 2013) is such an effort, by showing correlations between aspects of a person's behavior based on statistical analysis. However, without suggestions, the correlations are mainly for reflections, and are sometimes perceived as too obvious and lack of practical value.

In addition, a series of more sophisticated lifestyle technologies – eCoaching systems (Lentferink et al., 2017)– have been explored to assist people with daily health management in a wide range of domains, e.g., sleep (Daskalova et al., 2016), diet (Rabbi et al., 2015a) and smoking cessation (Wang et al., 2018b). Acting "not as a mere instrument, but as a coach" (Kamphorst, 2017), they help people identify and form goals related to a certain aspect of healthy living and offer an actionable plan consisting of personalized suggestions and feedback to achieve that goal. In general, with more tailored guidance and personalized insights and suggestions (Banos and Nugent, 2018), these technologies are considered more effective than generic online health information (Rutjes et al., 2016; Lentferink et al., 2017; Adams et al., 2013; Rabbi et al., 2015b), and recognized as a promising approach to encourage behavioral changes (Sas et al., 2020), suggesting new possibilities for everyday health management.

Overall, the work on lifestyle technologies has mainly focused on particular aspects of health behaviors, such as exercises and weight loss, and quantitative measurements of these behavioral aspects. Often relying on quantitative metrics and statistical analysis, not based on health assessment, they may lead to users' excessive pursuit of quantified goals such as over-exercising or over-dieting and thus cause negative health outcomes (Rich et al., 2020).

3. Background: TCM/Yang Sheng

As our work is based on TCM and associated Yang Sheng[2] practices, below we briefly provide some background information.

Traditional Chinese Medicine (TCM) is a system of medical practice that has developed its own substance, methodology and philosophy through long-term empirical testing and refinement. The efficacy of some TCM interventions, especially acupuncture (Witt et al., 2005; Liu et al., 2021), herbs (e.g., arsenic (Chen et al., 1997) and artemisinin (Dondorp, 2005; Tu, 2011)), has

[2]In Chinese, Yang (养) means "take good care of", "nurture", "maintain", and "conserve", and Sheng (生) means "life"

been proven by the criteria of Evidence Based Medicine and randomized controlled trials. A detailed description of the evidence base for TCM is clearly outside the scope of this paper, and interested readers can refer to (Tu, 2011; Linn, 2011; Pritzker and Hui, 2012) for more information. Overall, TCM treats health in a more holistic sense, or in other words, it focuses more on the state of the body as a whole than particular symptoms or diseases (Greef and Jan, 2011). Therefore, health assessment in TCM often involves systematical concepts to describe the relationship between the manifested signs and one's overall health status.

In particular, the concept of body constitution indicates how balanced one's body is and is often used to describe people's health status (balance means better overall health). It includes Balance (Yin-Yang harmony), Qi-deficiency, Yang-deficiency, Yin-deficiency, Blood-stasis, Phlegm-dampness, Dampness-heat, Qi-stagnation and so on (Wang, 2005). The determination of body constitution often involves several diagnostic methods, including facial diagnosis and inquiry (Liu et al., 2013). TCM regards a person's body constitution as mutable, and factors such as the living environment, mental state, diet, daily activities, and diseases can change it (Wang et al., 2012). The categories of body constitution have been widely applied in clinical diagnosis (Sang et al., 2018), treatment (Sun et al., 2010) as well as health maintenance and promotion (Li et al., 2019) in TCM.

For thousands of years, TCM has played an important role not only in medical treatment, but also in health maintenance (Cheung, 2011) in China and other Asian countries. When everyday health maintenance and promotion is concerned, it is mainly through TCM-based Chinese Yang Sheng practices. Yang Sheng involves many practical ways to take care of life before disease occurs by ensuring balance of the body through everyday living habits, such as eating and drinking as well as various techniques such as Qigong or Massage. Essentially, Yang Sheng is about ensuring the free and unobstructed flow of vital life energy (Qi). Qi is the fundamental element of the universe and the vital energy of all living beings, and it is believed that when one has abundant Qi, and energy can circulate smoothly and freely to all parts of the body, it can easily achieve balance and effectively avoid illnesses. Otherwise, the balance of body cannot be maintained, leading to weaker defense against pathogens and diseases. To draw a parallel with the well-understood Western medical concepts, Qi is roughly equivalent to metabolism, and balance is related to immunity and homeostasis (see (Cheung, 2011; Greef and Jan, 2011) for more details).

Yang Sheng also emphasizes harmony with the nature, by following nature's changes and applying appropriate practices to help foster health and well-being. For instance, the 24 solar terms[3] are used to reflect the change of seasons, which influences our health status, and different Yang Sheng practices are suggested for each solar term (Xu and Wang, 2018). In addition, one day is equally divided into 12 periods, and it is believed that each period corresponds to and is for nurturing a particular organ system. Besides these temporal changes, Yang Sheng also means taking other contextual changes such as weather into account when applying related practices.

Aspects of Yang Sheng have become globally popular, e.g., Yang Sheng exercises such as Qigong and Meditation have been undertaken as healing techniques for stress reduction (Wang et al., 2014) and for enhancing mindfulness (Chow and Tsang, 2007). In China, among the most commonly-shared information online is that related to Yang Sheng (Li, 2016). There is also sustainable growth among the young population who seek this information online, resulting in more than 10 million monthly active young users in 2016 (Meituan Research Center, 2016). TCM and Yang Sheng has its roots in ancient Chinese philosophy, particularly Taoism (Wang and Stringer, 2000), and some practice Yang Sheng not only for the pursuit of optimal health but also for the learning and understanding of Chinese philosophy.

In general, TCM puts stress on preventive health and treats health in a holistic sense, and Yang Sheng in particular is meant for health maintenance through everyday life habits rather than disease treatment, which is consistent with our design ideas. Additionally, computerized approach for health assessment based on TCM is already mature and popular, with body constitution as its theoretical basis and facial diagnosis/inquiry as its approach. For instance, the recent advancement of computerized face reading technologies has made it technically feasible for people to take a photo on a mobile phone and get their health assessed and monitored in everyday settings (Zhang et al., 2018). As such, we chose to design and build our prototype on TCM.

[3]Based on the positions of the sun on the ecliptic, in TCM, the 24 solar terms are used to reflect seasonal changes, phenomena of climate, and agriculture, and have been believed to greatly influence changes of health status in everyday life.

4. Ethical Approval and Consent to Participate

We obtained research ethical approval from the Chinese Ethics Committee of Registering Clinical Trials to conduct all the procedures of our study involving human subjects. The TCM doctors took charge of the collection of the facial pictures and data annotations used for the training of the algorithmic model of our system. In total, there were 150,000 voluntary participants who contributed their facial pictures, including hospitalized patients, out-patients, medical students and local community members. Before they took part in the study, they were fully informed that their facial pictures would only be accessed and analyzed for research purposes and would be kept credential and anonymous. They signed the written consent form prior to participating in the study. About the field trials, we also explicitly explained to our participants that we would only access and analyze the interview data and usage logs for research purposes, and their health and all the other identifiable information would be kept credential. All of our participants signed the written informed consent form to participate in our field trials.

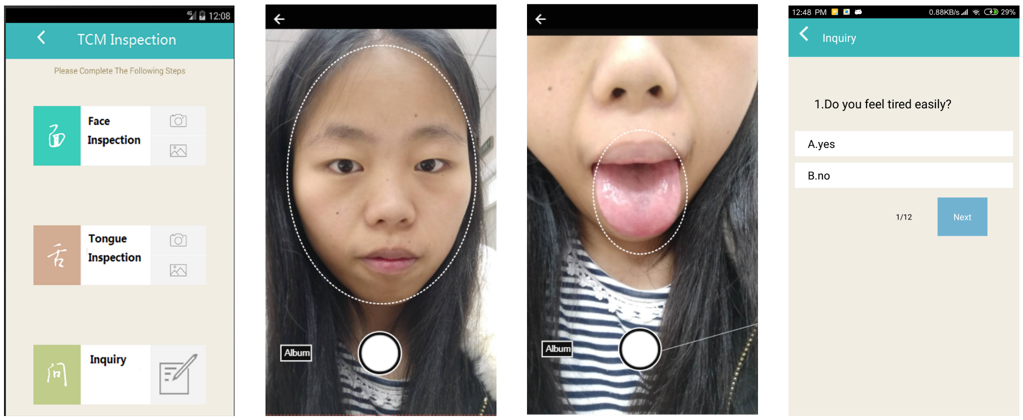
5. The Design Process

In this section, we describe the iterative design process of our prototype, a mobile application which employs TCM-based, AI-powered health checkup techniques, and provides a report with health assessment and corresponding health advice, including diet, drinks, physical activity, mood, etc. It is designed as a consumer-facing health application, meant for people to achieve optimal health through assessment and interventions of everyday life habits outside of clinical settings. Users are advised that it cannot substitute medical treatment and they should consult doctors when feeling uncomfortable.

We adopted an iterative user-centered design (Holzinger et al., 2008) process to ensure the functionality and usability of our design prototype and validate our design ideas, as described in detail below.

5.1. Stage 1: Technology Probe Study with A Health Checkup Application Based on Face Reading Technologies

To start with, we built a technology probe (Hutchinson et al., 2003) named *Faced* by incorporating all the necessary techniques from image processing, machine learning and TCM to provide users with a functional system to try out. We hope to learn about users' acceptance and actual usage patterns when bringing the originally clinical facial diagnosis into everyday use,



(a) main interface (b) face interface (c) tongue interface (d) inquiry interface

(e) results

Figure 1: Faced Interfaces. Faced is a health checkup application based on face reading technologies. As a technology probe in the pilot study, it helped us gather user feedback and explore design implications, based on which we made improvements and developed a new prototype named RegiBot.

and evaluate how it may contribute to everyday healthy living. Details of *Faced* along with the field trial can be found in (Ding et al., 2019). To provide context for this paper, we briefly describe the key components and findings of *Faced* with technical details.

5.1.1. The Underlying Algorithms

Faced employed two important diagnostic methods for the health status assessment: 1) a facial examination, including an inspection of the face and tongue and 2) an inquiry.

We cooperated with TCM doctors from Shanghai University of Traditional Chinese Medicine to develop the underlying face and tongue inspection model. According to (Liang, 2016; Hong et al., 2016; Zhou et al., 2018; Huan et al., 2017), facial and tongue features can reveal one's internal states, indicating possible constitutional types. Features selections and related rules are based on TCM theory (Zhang et al., 2013; Zhang and Li, 2014; Li et al., 2009, 2012) and instructions provided by the TCM doctors. Features selected include face color, face gloss, lip color, tongue color, tongue fur color, and tongue shape. A more detailed feature description and evaluation can be found in (Zhao et al., 2014; Zhang et al., 2018). To extract these features from facial photos, after the pre-processing of facial photo with color correction and image quality optimization, the images of the face and lip are cut out using image segmentation algorithms (Qiu and Zhang, 2015; Hu et al., 2016), based on which deep learning and SVM are employed to extract features and classify them into certain categories.

To ensure the accuracy and effectiveness of the model, the TCM doctors were involved in the whole development process. The facial pictures used for the training of the model were collected from 150, 000 volunteers from 10 local hospitals and 10 communities, all selected by the TCM doctors to ensure gender balance and age coverage. Training samples were collected in both the standard (using a TCM integrated diagnosis instrument with standard camera, light, and user posture) and the open (cell phone, indoor and outdoor) environments. TCM doctors annotated all the data, with each sample annotated 3 times by different doctors for cross validation. Samples with inconsistent annotations were removed from the data set, to ensure the validity of the ground truth for each sample. The diagnosis model was also evaluated using 2000 volunteers, with an accuracy of 85% compared to the results of the TCM doctors.

Besides picture analysis, there is also an inquiry process in the health assessment. By taking the inquiry results into consideration, we can further increase the accuracy of the final result. For the inquiry, the questionnaire and rules for determining constitutional types are provided by the Standard of Classification and Determination of Constitution in TCM (China Association of Chinese Medicine, 2009), which was published by Chinese TCM association and applied in national test units. The questions cover the topics of fevers and chills, sweating, head-body and chest-belly symptoms, taste and diet, stool and urine, sleep, and mood. Different responses to these questions indicate the inclinations of different constitutional types, based on which our algorithms were built.

As mentioned above, our application is designed as a consumer-facing health application. The application provides people with suggestions on everyday life habits rather than medical advice. In addition, users are advised that the health assessment cannot substitute medical diagnosis/treatment and they should consult doctors when feeling uncomfortable. Through these means, we ensure that the negative impact of potential technical errors on users is low.

5.1.2. Interfaces and User Flow

The interfaces of *Faced* are illustrated in Figure 1. In a health checkup, users will go through three steps - face photo collection, tongue photo collection, and the inquiry, as shown in Figure 1(a). For photo collection, users can either choose from the photos stored in the smart phone, or take a new one with the smart phone camera (see Figure 1(b)(c)). If the photo is not qualified (e.g., inappropriate size or lighting), users have to upload a new one, otherwise the facial inspection cannot be performed. After the photo collection process, users will enter into the inquiry process (see Figure 1(d)), and have to answer all the questions without skipping. After these steps, the model qualitatively classifies one's health status into certain body constitution, taking both the facial diagnosis results and answers to the inquiry into consideration. If the users do not finish all the steps or give up in the middle, no results will be generated.

After users complete the health checkup, they will receive a health report (see Figure 1(e)), including facial and tongue descriptions, a health score, a description of their health status, and corresponding advice for health improvement. Health advice was provided by the TCM doctors based on different constitutional types detected by the diagnosis model, and no information about the underlying analysis model is shown in the report.

Adapted from a system originally developed for TCM clinical diagnosis during medical visits, *Faced*, as a mobile version of it, is more easily available for everyday use and provides more suggestions for everyday health purposes. In other words, *Faced* is already technically feasible to be used for everyday health management.

5.1.3. Field Trial and Lessons Learned

We conducted a three-week study with 10 participants who paid attention to personal health and were interested in using new health technologies to field-test *Faced* as a technology probe. We had semi-structured interviews with the participants, and the field trial revealed potential use of it in everyday health context, helping users understand their health statuses and adjust lifestyles accordingly. A number of critical design issues were also identified in its use in everyday life. For details of our research method and the field trial, please refer to our previous work (Ding et al., 2019). Here, to give a more holistic picture of this work, we briefly summarize the critical design issues, including issues of adaptability, sensitivity, transparency and trustworthiness (Holzinger et al., 2022).

Lack of Adaptability. One important factor preventing the participants from using *Faced* more or even caused abandonment was that it always asked the same questions, which made the health check-up boring and burdensome. Also, the TCM-based qualitative health assessment result was likely to stay the same over a relatively long period of time, and so was the corresponding health information. Lack of adaptability to the user's personal data, and lack of variety in health information were causes for common abandonment, suggesting that a primary difference between everyday health technologies and clinical technologies is the support for sustainable use. Based on our findings, we suggest more adaptability of the design to better support sustainable use. Instead of asking fixed questions, the inquiry can be more adaptive to the user's personal health condition. Also, context-aware health information according to seasonal and weather changes can make the health report more adaptive, as advocated in Yang Sheng guidelines, meanwhile serving as a personalized way to learn health-related knowledge.

Sensitivity of Face Reading Technologies for Everyday Health. The use of facial images, and the change of settings made the use of *Faced* more contextually sensitive compared to other self-monitoring technologies. While technically, it was feasible to use *Faced* anytime and anywhere (as long as users can take a qualified photo), everyday settings were quite distinct from well-controlled clinical settings. In particular, the tongue photo taking was extremely sensitive to cultural and social norms in non-private situations; the accuracy of the diagnosis was also easily affected by external factors such as lighting and camera quality. Based on these findings, we suggest more flexibility for its everyday use. Instead of making the tongue photo collection a required step, we can make it optional. Although the result may be compromised, users can make their own informed decisions and a balance can be struck between less accuracy and broader usage.

Lack of Transparency and Trust Issues. When moving out of the more authoritative clinical environment and without the help from professionals, lack of transparency often led to impaired perceived reliability. The underlying algorithms were hidden from end users, leaving them no other way but their own perceptions to assess the results. In addition, the variability of contextual and equipment factors in everyday settings, although could be standardized by algorithms, was kept from users and resulted in their questioning the result's reliability. Finally, the numeric score given in the health report, although designed to be an indicator of health condition, turned out to cause negative reactions and possible distrust, especially when the score was not consistent with users' own perceptions of their health condition. Relatively low scores could also evoke negative emotional reactions.

Besides the negative impact on reliability, lack of transparency would also result in less user engagement. Limited health literacy led to difficulty in interpreting the results and assessing the health suggestions, especially when users could not get professional assistance during everyday use. In particular, the unfamiliarity of TCM terms kept users from engaging with the system more and putting the suggestions into practice.

In order to assist users in reliability assessment and increase users' engagement, we suggest more transparency in algorithm, context and health-related knowledge. We also suggest more qualitative description rather than quantitative scores to indicate user's health status in the health report, and provide more explanations related to user's constitutional type, in order to avoid possible distrust, misinterpretations of the results, or negative emotional reactions caused by the quantitative score.

5.2. Stage 2: A Chatbot-based Prototype with More Adaptability, Flexibility, and Transparency

Based on the user feedback and the design implications from the first pilot study, we made a series of improvements to address the design challenges, leading to the development of our new prototype named RegiBot (Regimen Bot). It is a standalone mobile application in the form of conversational agent, hoping to engage users in the interaction similar to health consultation with a doctor and guide users through the whole checkup process more naturally. It is designed with more adaptability, flexibility and transparency in mind. Next, we will describe the improvements in detail.

5.2.1. More Adaptability

The new prototype has been designed with more adaptability to better fit in users' everyday life. Although frequency of use may not be the most important measure for the value of health technologies like ours (Ding et al., 2019), sustainable and periodical use is still part of our design considerations as we believe that good health relies on periodic and long-term maintenance. To better support sustainable use, a major modification we made is that the health advice is provided based on the natural context, beyond only body constitution. According to Yang Sheng guidelines, which emphasizes health preservation according to environmental changes, we made the health advice more adaptive to different solar terms (each solar term has a time span of 15 days), time periods of the day, and weather. In this way, even when the user's health condition is relatively stable, they could still check the application to receive context-aware lifestyle advice.

To acquire more adaptive health recommendations, we employed web crawlers to obtain information from authoritative online resources supported by National Administration of Traditional Chinese Medicine, such as China Medical Information Platform (China Medical Information Platform, n.d.), and reputable Yang Sheng information platforms (Beijing Jinsheng Online Technology Co.,Ltd., n.d.; TCM Web Portal, n.d.). We also manually sought related information from some TCM classics (Wang, 2014). After careful data cleaning and structuring, we consulted TCM professionals to avoid potential errors and further improve our health advice. Finally, we constructed a knowledge graph to integrate all the information we collected using the Neo4j graph database on our server.

By detecting the time and geographic location of the user, RegiBot can obtain appropriate contextual information and make the health advice more adaptive and tailored to user's particular situation. Advice related to the current time period of the day is shown on the home page, making it easier for users to check and follow. As is shown in Figure 2(a), for the current time period, RegiBot provides a brief description of the corresponding meridian and energetic flow, as well as "do's and don'ts" to help users nurture the represented organ system. The health report is also adaptive according to current solar term and weather. For instance, during the 15-day period of the solar term End of Heat, the health report provides health-preserving principles, such as "You are Qi-deficient, and during End of Heat, people with Qi-deficiency should pay attention to eliminating dampness and preventing cold.", as well as more detailed suggestions on diet, drinks, exercise, daily routines, and mood. Each day, targeted advice is given based on the weather, like "avoid outdoor exercise due to the high temperature".

Another adaptive design is the inquiry part. Based on the analysis of user's face and tongue inspection results, RegiBot generates a possibility distribution of different constitutional types, and asks questions accordingly. Taking both face and tongue features and answers to precedent questions into consideration, each inquiry question is dynamically chosen from the database, making the whole inquiry process more adaptive to user's personal condition.

5.2.2. More Flexibility

To address the sensitivity issues of face reading technologies and make it fit more easily into the varied and unpredictable everyday settings, the health checkup process has been designed with flexibility in mind. We employ a chatbot to streamline the interactive process of the checkup, following the design conventions of popular messaging apps, with message bubbles of different colors indicating instructions, RegiBot's responses and user's input.

During the checkup, users are allowed to skip steps if they like, with a reminder of possible impact on the accuracy of final result in a red message at the top of the result interface (see Figure 2(e)). In this way, users can make their own informed choices as whether to skip, to strategically fit it into the situations they were in, e.g., at home, office or a public space. Also, to help users take a qualified photo in more difficult settings, instructions are provided in a message bubble that appears before users upload photos (e.g., natural light is preferred, the proper position of the face or tongue (see Figure 2(b)). Users are allowed to upload a new photo to replace the existing one, in case they are unsatisfied with the lighting, photo resolution, etc.

5.2.3. More Transparency

We also improved the transparency of our design by providing results and explanations after users finish each step and before the final health report is generated. Users can view the detailed description of their face/tongue in a more visualized way, as shown in the detail interface (see Figure 2(d)). Besides text descriptions, RegiBot uses color blocks and icons to indicate different facial features (face color, face gloss and lip color), and provides explanations about the relationship between specific features and the user's health condition.

In addition, more transparent explanations are also embedded in the health report, with rich health-related knowledge and rationales behind suggestions to facilitate trust and learning. Instead of quantitative health score, we choose a more qualitative way to describe user's health condition. Specifically, to help users who may not be familiar with TCM terms, the health report contains qualitative description of user's constitutional type, and more details of corresponding symptoms, causes, therapies and descriptions of the face and tongue (see the first figure in Figure 2(e)). For the health suggestions based on user's constitutional type, we not only provide adaptive and practical suggestions on recommended and unrecommended food and acupressure methods, but also give detailed explanation and the rationale behind the suggestions (see Figure 2(e)). Therefore, users have more information to assess whether the health advice is suitable for them, and can learn more about health and wellness at the same time (Holzinger et al., 2010).

5.2.4. User Flow

With these improvements, the new prototype works as follows. When users open the application, they first see the home page as shown in Figure 2(a). The lower half is adaptive advice based on the 12 two-hour periods of the day for users to follow. Users can click the upper half of the home page to enter the main interface for a health checkup.

The whole checkup process is conducted in the form of chatbot (see Figure 2(b)(c)), composed of a face inspection, tongue inspection, and inquiry. As is shown, RegiBot first asks users to take a photo of their face with their smartphone's built-in camera or to choose from the album in their phone. Users can choose to skip the step, or upload a photo as instructed. After several seconds of back-end processing, RegiBot either presents a brief result of the face inspection using TCM terms, or responds with a message saying that the photo is not qualified, and users are free to upload a new photo to replace the existing one. After the face inspection, RegiBot asks users to upload a tongue photo, and the process is generally the same as the last. When users finish each step, they can view the detailed description of their face/tongue in the detail interface (see Figure 2(d)). Finally, RegiBot guides users through the adaptive inquiry process, with several preset options for users to select from, allowing them to provide a quick response (see Figure 2(c)).

Based on the analysis of the user's photos and inquiry data, the user's constitutional type is identified. A health report is then produced containing the user's type with a short description, details of corresponding symptoms, causes, therapies, descriptions of the face and tongue, and corresponding health advice based on their identified constitutional type, current solar term and weather. The report will also be automatically saved locally to the user's smartphone for later review.

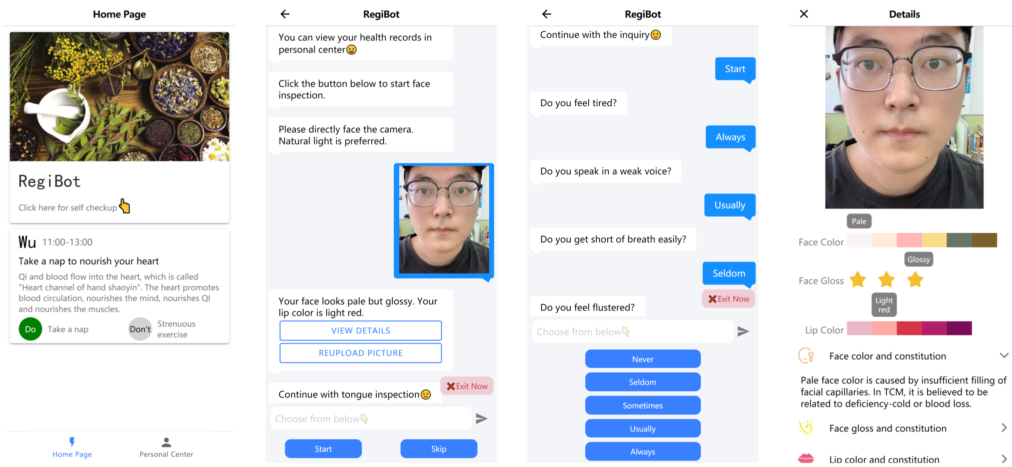
As such, based on TCM for overall health assessment in terms of constitutional types and offering suggestions by taking constitutional types and contextual factors into account, we have adopted a qualitative, personalized and adaptive approach to the presentation of the health advice, thus making RegiBot a more holistic approach to health than simply focusing on particular aspect (e.g., sleeping or exercise), and is also more personalized and tailored to users' particular situations.

6. The Field Trial and Data Analysis

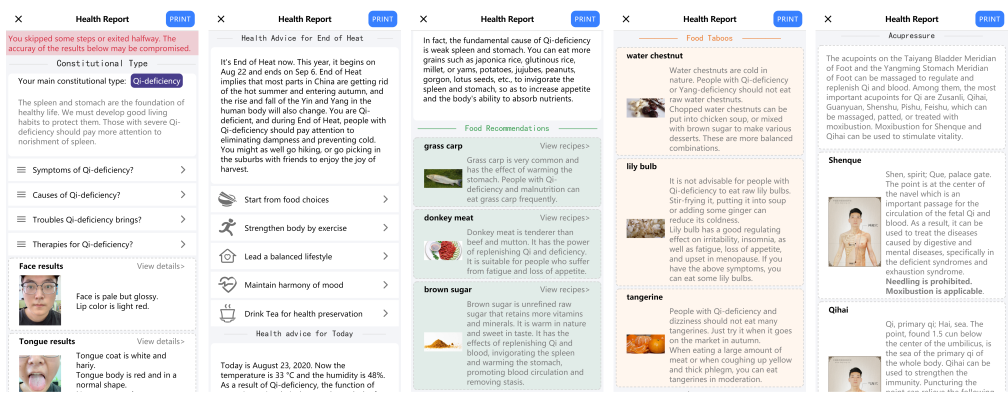
After the iterations of improvements, we conducted a field trial with the new prototype (RegiBot), as part of our iterative study. The purpose of the field trial is twofold: 1) to test whether our improvements actually address the critical design issues uncovered in our stage 1 study (Ding et al., 2019) and make the application more user-friendly; 2) to understand how an intelligent health technology actually works and how to design it to better support healthy living in everyday lives. Our study was reviewed and approved by the Chinese Ethics Committee of Registering Clinical Trials.

To recruit participants, we distributed recruitment flyers in our own social networks using WeChat[4] Moments[5], some Yang Sheng-focused WeChat groups, and an offline Yang Sheng club. Initially, 18 people applied to try out the technology. We conducted initial interviews to learn about their understandings and former practices of TCM/Yang Sheng, and whether they would like to formally participate in our study. Three chose not to participate because they were not actually interested in healthy living based on TCM/Yang Sheng (and they were just curious about the face/tongue inspection and asked for a try), and two quit the study due to their busy schedules. In the end, we recruited 13 participants for the field trial. The detailed profile information of our participants is shown in table 1. We offered each participant 100RMB as compensation in recognition of their time and contribution.

[4]A popular messaging App in China
[5]Similar to the Facebook Timeline or the Twitter News Feed



(a) home page (b) main interface, face inspection (c) main interface, inquiry (d) detail interface



(e) results

Figure 2: RegiBot Interfaces

We then conducted a 4-week field trial with the 13 participants. We didn't require any compulsory use, so the users were free to use the application at any time in the four-week period, but we did do experience sampling (Consolvo and Walker, 2003) by contacting them to talk about their use, especially when we observed their use in our logs, to learn more about the details of their experience while their memories were still fresh.

After the 4-week field trial, we conducted exit interviews with participants. Each interview lasted for approximately 1 hour. We used their logs

Table 1: Participants for the second study. Participants are designated by pseudonyms.

ID	Gender	Age	Education/Occupation
Ye	F	20s	Undergraduate Student
Yan	F	20s	Designer
Yi	F	20s	Undergraduate Student
Di	M	30s	Office Worker(Logistics)
Chen	F	20s	Designer
Weiran	F	20s	Undergraduate Student
Qin	F	40s	Office Worker(Insurance)
Ting	F	20s	Undergraduate Student
Kong	F	20s	Undergraduate Student
Li	M	20s	Office Worker(Customer service)
Zhen	F	30s	Office Worker(Finance)
Yu	F	30s	Office Worker(Advertising)
Fang	F	40s	Office Worker(Night shifts)

and the feedback we received during the trial period as cues to ask specific questions about their use practices. We asked for details about their usage cases, as well as the specific usage context, e.g., when and where the application was used, whether there were others around. In addition, we inquired into users' own perceptions and interpretations of the results, and whether they had put the health advice into practice. Finally, we encouraged participants to talk about how they would want to use this kind of application for everyday health purposes and what new features they would like it to have.

The communication and interviews with our participants mainly took place online via WeChat voice calls, except the communication with Qin, which took place in the offline Yang Sheng club. We audio-recorded the interviews with the participants' permission and transcribed them for data analysis. We conducted all interviews in Mandarin but translated all quotes presented in this paper to English. We performed thematic analysis (Braun and Clarke, 2006) inductively on the interview transcripts. The authors first coded and analyzed the data independently, by reading the data and marking the ideas. Each then started compiling a list of codes. We then had meetings to discuss the ideas. Together we compared, refined, and consolidated the codes through iterative discussions of the most salient data, i.e., recurring patterns and surprising behaviors. We eventually curated codes into a set of themes, and arrived at the findings as presented in the next section. To protect our participants' privacy, when reporting our findings, we use pseudonyms to denote our participants.

7. Findings

While our former research on *Faced* uncovered design challenges which made many abandon the technology early on (Ding et al., 2019), our log and interview data of RegiBot shows no abandonment in terms of un-installation during the field trial, suggesting our improvements on adaptability, flexibility and transparency worked well to address some of the usability and design challenges uncovered from the first iteration. In this section, we will focus on elaborating the actual usage practices we found from the study.

7.1. An Overview

During the field trial, we found that some participants (Chen, Ye, Qin, Yi, Li, Yu and Fang) used the App more often – each conducted the self-checkup about 8 times and checked the App for health recommendations more than 15 times throughout the study period, whereas others used it more sparingly – each conducted the self-checkup about 4 times during the first two weeks and only checked the App for about 5 times afterwards. Based on our interview data, the reasons we identified of their decreased usages over time include the diminishing novelty, busy schedules (Yan, Qin, Kong), and self-perceived stability in their health status (Yan, Di, Weiran). Generally, those who lived in a family with a Yang Sheng tradition showed more interest in using RegiBot for their everyday health. Interestingly, most of our participants were young people in their 20s or 30s, contradicting the general belief that Yang Sheng is less popular among the younger generation. This is probably because younger people are typically more skilled at and knowledgeable about using new digital technologies for everyday health, such as BooHee[6] for nutritional advice (Ye, Di, Kong), KEEP[7] for exercise plans (Ye, Chen, Ting, Kong, Yu), and online Ask the Doctor services (Ding et al., 2020) for consultations, which may also account for their interest in such a new health technology.

[6] The largest mobile weight-loss platform in China

[7] A mobile fitness community that offers a variety of training programs for different groups of people

Participants generally found that RegiBot was easy to use and understand. In particular, they liked the conversation-based health checkup, as the dialogue form of interaction has similarities to the offline consultation with a doctor. They also appreciated that the health advice provided was more systematic and more tailored to their individual situations compared to the information they could access from other people, social media, or other health-related applications. They perceived the health reports to be mostly accurate: the constitutional types were consistent with their own past medical checkup results with TCM doctors, and the descriptions matched their own experiences. When perceived inconsistencies arose in the results, they tended to attribute them to their own inputs to the health checkup, such as their photo not being taken appropriately or having been unsure of how to answer some of the inquiry questions, indicating a higher level of trust with the technology compared to the field trial with the first prototype.

In general, this field trial yielded rich data of how this kind of application may be used in everyday life to foster healthy living. Below we will first present the characteristics of effects the application might bring into users' lives, and then show how the temporal adaptability triggers corresponding usage patterns, how the flexibility helps fit it into complex everyday settings, and how the transparency supports reflection, internalization of health-related knowledge as well as enhancement of sensitivity.

7.2. Potential Effects: Enforcement and Micro-adjustment

The study suggests that the use of RegiBot does have some effects on our participants' lives. Overall, based on the interview data, we found the effects were mainly about enforcing existing good habits and making small adjustments on unrecommended lifestyle choices, rather than radical changes.

We found that our participants tended to be selective in terms of what suggestions to pay their attention to or actively follow, and these were mainly based on their existing habits, personal likes, and prior knowledge and experience accumulated over their exposure to TCM related information from family, media or TCM doctors. For instance, Ye reported a case: "*In a recent use, the application recommended eel to me. I quite like eel myself, so I remembered it clearly and ate it more often.*" Yan also found that the suggestions confirmed her existing eating habits: "*When I read the health report, I found that most stuff it recommended are something that I tended to eat regularly already, such as lotus leaf and tremella, so I felt I have eaten the right things.*" Similarly, Fang was even more convinced about the benefits of red beans and coix seeds: "*TCM doctors and people around me all told me that red beans and coix seeds can expel dampness. Seeing the same suggestion from the application, I'm more convinced that it is good for my health.*" As such, one of the effects is enforcing and reaffirming users of their existing awareness, habits, and personal likes. Or in other words, their existing awareness, habits and personal likes became a natural filter for corresponding advice.

When RegiBot recommended that participants avoid something they either really liked or could not fully avoid, they commonly compromised and tried to mitigate its negative impact by taking certain measures. For example, Fang chose to wait until the watermelon reached room temperature: "*Since I know my constitutional type is Phlegm-dampness, I always say no to cold drinks or food. However, with the heat today, I can't help eating watermelon (considered as "cold" in TCM). Instead of eating it right after it comes out from the refrigerator, I chose to wait until it reaches room temperature.*" Kong hoped drinking more hot water would help compensate for drinking cold water sometimes: "*I know less cold food is good for me, but I cannot strictly follow the suggestions. So I drink hot water everyday, hoping to compensate for it.*" Di changed the frequency of eating certain things that were not recommended for him: "*I can't totally give up some food. Cole used to be my favorite, but now I only eat it once in a while.*" As such, for things participants really liked, but that went against the App's suggestions, some kind of adjustments were made rather than radical changes.

In general, health suggestions that only require a small adjustment rather than big changes are more likely to be followed and put into real practice. For example, Ye commented that the recommended exercises were easy to do: "*The exercises RegiBot recommends are pretty easy to do, like taking a walk or jogging. Most are quite easy to follow.*" She also commented how some health tips could be easily adopted: "*It gives you some health tips such as wiping the sweat immediately after exercise instead of waiting for it to dry naturally, and waiting for some time rather than taking the shower directly. These are all small things that we can easily adopt in daily life.*" Yan changed when to go to gym: "*I used to hit the gym after work, at around 7pm or 8pm. After using the App, I found that it was not good to work out so late at night, so I changed it and go to the gym at noon.*"

On the other hand, suggestions that appear too demanding are less likely to be adopted. For example, Yu explained how she took two suggestions differently: "*It asks me to go to bed and get up early most of the time. To be* *honest, I cannot do it. However, I will adopt some small tips like blowing dry my hair (after a bath).*" Fang also thought it was impossible for people who worked the night shift not to have night-time snacks: "*Staying up late and having night-time snacks are something I can't change. It's impossible for people who work on the night shift not to eat something.*"

Indeed, we found that our participants were really sensitive towards the extra work involved in following the suggestions. Most of our participants are still young, and are in the transition from living with their families to living on their own. For some lifestyle suggestions, such as dietary suggestions, living with one's family or not can make a big difference. For Ye, following the dietary suggestions could be as simple as telling her parents what to make. In contrast, Yu, who lives on her own and considers cooking as cumbersome, felt the dietary suggestions were not easy to follow because "*some of the recipes are not detailed or easy to prepare*". Participants also suggested various ways for RegiBot to help reduce the work of following the suggestions, such as combining with recipe Apps to get more details on how to cook the food and linking to products that could be directly ordered online.

7.3. Temporal Adaptability and Usage

As mentioned previously, lack of adaptability to user's personal data, and lack of variety in health information caused early abandonment of the first prototype *Faced*. To better support sustainable use, in addition to one's health status, based on TCM/Yang Sheng guidelines, RegiBot took environmental factors into account when providing advice, such as different time periods of the day, solar terms, and weather factors. Our participants frequently utilized this more adaptive advice, and as a result, exhibited a periodic or rhythmic use of the App. As these suggestions corresponded to the time when users opened the App, they also served as a timely intervention and led some to take immediate action. Moreover, participants suggested the potential of integrating tracking functions for more effective long-term care.

7.3.1. Periodic Use

We found that some participants' use of RegiBot was rhythmic and periodic. Our participants all appreciated that the health advice corresponded with natural rhythmic changes, mainly the solar terms and the time periods of the day. Some specifically checked the application during the time of the solar term change to see how the health advice would change. For instance, Yu reported: "*The Beginning of Autumn came recently. It's time to take a* *look, and see whether there is any difference [in health advice], so I used RegiBot.*" Fang also demonstrated a similar use.

In addition, some participants recognized that according to Yang Sheng, there are natural fluctuations in one's health status in terms of constitutional type. This knowledge led them to seek a periodic and regular checkup. Fang said: "*It has been some time since my last use of the application. Maybe my constitutional type has changed, so I wanted another health checkup.*"

However, in its current version, RegiBot does not provide any reminders about the changes of solar terms, or guidance on how frequently one's constitutional type may change. Our participants commonly considered that reminders about the upcoming solar term changes could get them prepared since sometimes, special foods are highly recommended for that day (e.g., lamb for the Great Heat for some health conditions). For instance, Qin suggested: "*We need some heads-up before a solar term comes, so we can be better prepared. It'd be great if RegiBot could inform us of the change, and push the health advice a few days before that day.*" More guidance on when to get a checkup is also needed, as Chen said: "*If RegiBot could remind me to make a self diagnosis on a regular basis, whether based on solar terms or fluctuations in constitutional type, I would be willing to. However, I don't know how frequently we shall do it.*" Thus, providing timely reminders and instructions on when to get a checkup would be very valuable to support the active health management loop.

7.3.2. Timely Advice

Participants also liked the adaptive advice based on the 12 two-hour periods of the day rooted in TCM. Our study suggests that such an adaptive approach provides timely advice and intervention for people to take action accordingly. Yan's case was a telling one: "*I remember once I checked the App at around 11 am or 10 am, and found that it was a good time for muscle exercises... so I started exercising.*" Di reported adjusting his life according to the timely advice relevant to his health situation: "*My stomach is not that well... If I wanted to work overnight, and this application told me [it is time to nurture stomach], I would tell myself, you have to rest for now ...*"

Currently, the application does not send reminders, and only shows advice when people turn it on. As a result, users may miss the advice relevant to their situations. Most participants told us that they would like to have timely notifications to further remind them to take appropriate actions. For instance, Weiran said: "*I hope the App can push some notifications to me.*

For example, 'It's Wu (11:00-13:00) now. Remember to take a nap after lunch', or something like that." Ting also expressed that a feature like this would be helpful, as she often forgot to check RegiBot at a particular time and would miss the information she wanted.

Interestingly, some participants also complained about the constraints imposed by the design, limiting what they could learn. For example, Yu was curious to learn more about the "do's and don'ts" for all the time periods, but could not get information related to hours in the middle of the night as she was sleeping then: "*There is nowhere you can see all the information about the 12 two-hour periods. Actually I am curious about it, but it's just impossible because I have to sleep!*" Based on this feedback, and for the purpose of providing users with the opportunity to learn, we may consider providing options for people to check out the full day's information when needed, and not simply the ones applicable to the current moment.

7.3.3. Persistent Tracking

Our participants commonly believed that, unlike medical interventions that offer quick effects, this type of lifestyle intervention required persistence before any results could be seen. For example, Ting was aware that dietary therapy took time: "*Eating particular foods won't give immediate effects, so I have to stick to it in order to see changes.*" Weiran also believed that effects would only be seen after a period of persistently healthy eating: "*Such advice takes long term persistence to be of any help for subhealthy issues. If you only eat the recommended food once today, actually it won't be of any help.*"

At the same time, however, participants also clearly saw how RegiBot could support their persistence in the long term (e.g., through health tracking, although RegiBot does not have a dedicated tracking function). Our participants commonly turned to the App to gain feedback and check their progress when some efforts had been made. For example, Kong explained why she used RegiBot on a particular day: "*I did a lot of exercise recently. I think there may be an obvious change in my health state, so I used RegiBot today.*" Similarly, Fang liked to regularly use RegiBot to check whether there was any improvement after she put the health advice into practice. For Yan, seeing progress helped her keep up the healthy habits: "*With it, I know what health status I am in. If I was Qi-deficiency or something, but it shows I'm improving now, I will stick to my health practices.*" Yi actually saw the effects of her efforts using RegiBot and was excited about it: "*There was a time when I suffered from insomnia and angular cheilitis. My diagno-*

sis result then was Yang-deficiency, and RegiBot told me it's due to spleen deficiency caused by too much cold food. After I paid more attention to my diet, I recently found that I returned to Balance." As such, because improvement takes time, getting feedback or showing progress on the application was important for participants to be sure they were going in the right direction; this reassurance helped them persistently stick to the healthy life choices.

Some actually made specific efforts to ensure the effectiveness of comparable tracking in everyday settings. For example, Yi deliberately controlled when and where she used RegiBot for checkups, so that results could be comparable over time, as she was afraid that different lighting would affect the accuracy of results: "*I usually make a self diagnosis in the morning, in my bedroom. Different lighting conditions may influence the accuracy of face inspection, right? The same environment can ensure the consistency of results, so they will be comparable over time.*" Overall, participants saw that RegiBot could be used to help track changes and assess the effects of their new habits over time, especially when they were trying something new and slow to take effect, such as dietary therapy.

7.4. Flexible Checkup and Situated Use

As mentioned, the checkup process was designed with flexibility in mind to better fit into complex everyday settings. We found our participants did take advantage of the flexibility of checkup by skipping certain steps, and one primary reason was related to accuracy. More specifically, wearing makeup, or lips being stained by food were some particular situations where our participants skipped face inspection, when they found that rigidly following the steps may actually lower the checkup's accuracy. Flexibility was also leveraged to address the sensitivity issues related to taking photos of face and tongue for checkup (Ding et al., 2019). In this study, similar to what was found in (Ding et al., 2019), most participants reported only taking photos for checkup when nobody was around, or only those with whom they were intimately connected, to avoid possible embarrassment or inconvenience in public. As such, being able to skip the tongue inspection allowed Yan not to "*offend others unintentionally*", and made Yu "*feel more comfortable*".

Interestingly, we also found the "strangeness" of the face and tongue inspection made the use of the application more socially visible to others, and attracted participants' family members and intimate friends to try it out. Li gave an example of this: "*My girlfriend was there, and she also tried it out. She saw me using this application, assessing health status by taking a* *photo. She thought it was fun.*" Yi had a similar experience: "*Usually there was nobody around. Today my mom was here, and saw me taking photos and sticking out the tongue. She asked for a try.*"

As another use of flexibility, some would also skip steps if they didn't expect any changes in the ongoing inspection process. Yu explained: "*If there are few variations in my answers to the inquiry, I will skip the inquiry part unless I can feel obvious changes in my body.*" Ye also felt that there was no need to repeat the same process again and again during a certain period of time: "*From the result of face and tongue inspection, I could expect the same questions to follow. If the questions and my answers remain the same [as last time], I usually skip the inquiry since I feel it won't make much difference.*" This finding suggests to us that when users skip steps, we can leverage the corresponding past ones; this would make the process even more flexible, but not necessarily at the cost of sacrificing accuracy.

Most of time, when condition permitting, participants would rigidly follow the three steps to achieve better accuracy. Fang chose to never skip since accuracy was of primary importance to her: "*As long as I've started the self checkup, I will finish all the steps and read the information carefully. I will not skip.*" Similarly, as shown earlier, Yi would make efforts to control any uncertainty, such as doing every checkup at the same time of the day and at the same location so that her results were accurate and comparable. For others, after trying different compositions of steps to do the checkup, they noticed differences between results and the potential impact of skipping steps, which led them to take the checkup process into account when evaluating results. For example, Yu noticed the difference between two checkups: "*In my first checkup, I only did the inquiry part. The result was different from the second time, when I only did the face inspection. I guess finishing all the three parts of diagnosis can generate a more accurate result.*" Kong also attributed the inconsistency she found to the different checkups she used: "*I tried the face inspection and tongue inspection, and it was interrupted. I came back and only tried the inquiry. The two results were a bit different...*" After that, she followed the checkup steps more rigidly to ensure accuracy.

Taken together, with the flexibility built into the application, we allow users to take various factors into account, such as makeup, lighting, privacy, the appropriateness of certain actions, as well as convenience to decide how they make situated use of the health checkup to get acceptable results.

7.5. More Transparency, Reflection and Learning

As mentioned, lack of transparency made it difficult for users to engage in the checkup process, interpret the results and assess the health advice. To solve this issue, we provided more transparency with detailed explanations, specifically focusing on health-related knowledge. In the study, participants exhibited reflective engagement with related information - they drew on the checkup process, results, and personalized and adaptive advice to think about their bodily experiences, their own likes and dislikes, and causes of their health issues, potentially leading to learning and enhanced health literacy.

7.5.1. Reflective Engagement

Our study suggests that participants' engagement in the checkup process was not merely seen as a way to get health results, but was also appreciated as a reflective process to examine one's health and everyday life, and develop awareness. As mentioned, we intentionally designed the inquiry step of RegiBot to be adaptive so as to reduce the number of questions for users to answer, making this step less cumbersome. However, while some appreciated this adaptive feature, and even described it as a "surprise" when they discovered it, we also saw a few cases in which our participants complained that there were not sufficient questions to answer. Fang made it explicit that she wanted to answer more questions: "*To be honest, I don't have a clear idea of my own health condition. By answering these questions, I have the chance to reflect on my body and feelings more carefully.*" Answering the questions is not seen as a burden to bear, but an opportunity for her to reflect on her body and develop more awareness about her health condition. Qin also complained that the questions were so few that she felt her reflective process got interrupted: "*The number of questions is somewhat insufficient for me. Eight to ten questions may be more acceptable, but now there are only six questions. I felt as if my reflection on my body was interrupted when it had just begun.*" As such, rather than being merely instrumental to getting a result, the checkup process itself was meaningfully engaged by participants.

Our participants also engaged in reflection when reading the results of face and tongue inspection and the final report. They tried to understand the results and examined their own perceptions about the descriptions, (e.g., whether they experienced the typical health symptoms indicated by their facial features). For example, Fang's facial inspection results showed that she might feel lethargic, so she carefully considered it: "*My facial diagnosis result triggered me to carefully reflect on my life, for example, whether I feel* *lethargic recently as indicated by the result.*" By reflecting on their results, users could understand their health statuses better and notice something they may have neglected in their daily life. The qualitative and somewhat ambiguous descriptions of how their results manifest physically helped them reflect on their own life experience.

Moreover, the fluctuations in diagnostic results easily raised their awareness of recent life habits and led them to reflect and, based on the report, find the cause of the change. Yi reported such a case. She had been diagnosed with Balance, but once it changed to Yang-deficiency. She then examined the report more carefully and reflected on her recent behaviors to find out what might have been the cause: "*I was diagnosed to be Yang-deficiency last time...I checked the report, and it described some of the symptoms that matched my own situations quite well. It mentioned period pain, and I did have period pain this time. It might be because I had been eating watermelon (considered as "cold" in TCM) and drinking icy drinks recently...and a few days ago I was wearing short cloth with uncovered midriff, which might cause the change.*" On the other hand, Kong was very happy to see that her result returned to Balance, and thought it was due to her recent exercise: "*One month ago I was Qi-deficiency and Yin-deficiency, but now I returned to Balance. I feel very happy. Probably because I have been doing exercises recently. I easily felt fatigue before, but I feel good and energetic now, so the change was consistent with my own feelings.*"

Besides the differences among one's own health results, differences across users were also helpful for reflection and reasoning. Comparing her health report with her mother's, Yi developed a deeper understanding of her own results: "*My mother had a health checkup today, and her result (Blood stasis) was totally different from mine (Balance most of time). I read the potential causes for her constitutional type, and discovered that it's probably related to the difference in our lifestyles.*" Li wanted to compare his results with someone else's to understand them better, but had not found a way to do so: "*I used it for checkup then, and it was Balance, then I gave it to my girlfriend to try it out and hers was also Balance...um...both Balance, and I haven't seen other types.*" He further suggested that RegiBot could provide more results for users to compare themselves with, so as to better assess their own conditions: "*With this, I only know about my own state of tongue. I'm eager to learn about other people's states of tongue.*" The current version only shows users their own results, and this feedback reminded us that we can enhance their reflective capabilities by showing all possible results.

Taken together, the self-reflection process could be facilitated with more awareness triggered by the inquiry process, more transparency scaffolding with knowledge and qualitative and personalized description, and social comparison as well.

7.5.2. Learning and Enhanced Sensitivity

The effects of RegiBot were not simply behavioral changes; more fundamentally, internal changes happened as well, through the reflective engagement process. Through using RegiBot, our participants gained a better sensitivity of their bodies and health status. For instance, for Yu, it was an enhanced sensitivity of her own body, instead of any actual practical suggestions, that helped her maintain her health: "*Actually I may not follow the health suggestions strictly in daily life, such as what to do in this period of time, because I hate constraints. Rather, to know better my own health state and what will make me uncomfortable are things I really care about...I have remembered some questions in the inquiry part, so I can examine my own body accordingly.*" Similarly, Ye reported how engaging in the tongue inspection helped her develop an awareness of the state of her tongue for assessment of health. RegiBot also helped participants develop a better understanding of the rationale and knowledge behind some health suggestions, which assisted them with implementing some suggestions into practice. As Fang told us: "*[RegiBot helped me develop] a deeper understanding of food. Through this, I can pay more attention to my diet.*" Through the use of the application and by engaging in the health checkup and personalized health suggestions, participants gained better awareness of their own bodies and personal capabilities of managing health. Such internalization of the sensitivity and suggestions might be more fundamental than just changing behavior.

Regardless, while participants might not be willing to make a big effort to follow the advice as mentioned above, the internalization of the suggestions allows them to practice some of them when opportunity presents. Yan reported that although she did not make food herself according to the suggestions, when she was ordering food at a restaurant, she would take the suggestions into account: "*I didn't intentionally try out some eating advice such as lotus leaf and bitter gourd. However, it came to my mind when I was ordering food [at the restaurant].*" Di said he would make the right choice when he happened to see some of the suggested food readily available: "*When I happen to see some of the recommended food in the canteen, such as Chinese yam or coix seeds, I will choose them.*"

8. Discussions and Implications

In the preceding sections, we presented the iterative design process of our prototype and corresponding findings from the field trial. It does not only show that the new design, featuring adaptability, flexibility and transparency, addresses the challenges uncovered in the first iteration (Ding et al., 2019), but also reveals rich data to show how the combination of self-checkup and lifestyle technologies might work for healthy living in everyday settings. By incorporating various intelligent components, including a conversation agent to engage in dialogue with users, an AI-powered face examination, an adaptive inquiry, and corresponding health suggestions based on checkup results and natural rhythmic changes, RegiBot presents one form of leveraging intelligent technologies to bring preventive health into everyday lives. From this study, it is clear that such a technology, while reminding people of a clinical consultation in its dialogue form, is perceived as distinct from clinical disease diagnosis, treatment, and management; rather, it has been mainly understood to conveniently address sub-health issues and support optimal health through everyday lifestyle choices. Compared with the health-related suggestions people could access from the Internet, which often suffers from unknown quality of information (Cline and Haynes, 2001) and being too generic without considering personal differences (Jacobs et al., 2018; Rabbi et al., 2015a), what this kind of technologies offer is a more personalized and intelligent way to support healthy living. Our study is based on TCM, which is developed from and mainly applied to Asian population, and one month is still too short to say too much about adoption; nonetheless, the field trial suggests more general and rich implications for the design of intelligent technology for everyday healthy living. Below we discuss them in turn.

8.1. Understanding the Nature of Health: Designing for Regular Maintenance, not Repair

In recent years, increasing research attention has been turned to promoting healthy living, or "preventive healthcare", as opposed to disease management, for it promises a reduction in the prevalence of diseases and better health outcomes with less cost. However, as shown in our study, designing for healthy living imposes more challenges than designing for disease-oriented management. One primary reason for this is that while health is important for everyone, many do not actively pay much attention to it until their bodies experience certain "breakdowns", e.g., diseases, symptoms, or collapses.

Former research has pointed out that when our homeostasis is disrupted (or in other words, the balance of the body cannot be maintained), we will get signals from our body; however, most of us often lack the sensitivity to perceive or even suppress the signals our body is sending related to its internal processes, finally leading to breakdowns of health (schraefel, 2019).

In a sense, health and wellness to us can be seen analogously to the role of "infrastructure" (Star, 2002) in our society. Both usually work in the background, silently and invisibly supporting our daily activities, without drawing much of our attention, until one day there is a breakdown, upon which they become visible and "present" to us (Heidegger, 1988; Star, 2002), and we examine it and try to fix it. Disease treatment and management are similar to most task-oriented work that we are familiar with, with the attention, goals, plans, expertise and collaborations needed to carry it out. In contrast, healthy living is essentially the matter of maintenance; what is needed are regular checkups and the ability to remove any potential risks to ensure it works smoothly. However, while there are usually workers regularly maintaining our infrastructure so that it can work smoothly and invisibly to most people, for health, not many have the awareness of the need to maintain it. This may partially explain the design and adoption challenges of self-tracking and persuasive technologies (Consolvo et al., 2006; Cordeiro et al., 2015; Röcker et al., 2014) which are meant to promote more healthy living, and people often feel a lack of motivation to use these technologies continuously (Choe et al., 2014), probably the cause for the common abandonment of such technologies (Clawson et al., 2015; Epstein et al., 2016).

With our prototype, it is through its adaptive design, based on TCM which has explicit and practical guidance on living our lives according to natural rhythms, that it invites periodic or rhythmic use. In the study, we found that these rhythmic changes were taken as opportunities by users to turn to the App to do checkups, examine their health, and receive timely and personalized advice accordingly. Participants would have liked to have even more clear guidance of periodic use of the App. Not all intelligent health technologies, of course, need to employ the same adaptive strategy to indicate regular maintenance, but some kinds of strategies to inform and assist users to take regular care of their health are important. After all, health itself is a dynamic state of wellbeing (Bircher, 2005), so designing for regular health maintenance may also benefit from taking temporality into consideration (schraefel, 2019).

For regular maintenance, we also believe it is not enough to just send recurrent reminders, and our study suggests several implications for design to support health maintenance over time:

- It is important to regularly provide something new or different to engage users' interest in self-care. As shown in the study, many times, the reason our participants came back to the App was because they expected to see changes and to learn something new.

- It is significant to reduce unnecessary workload for users to follow the suggestions. As illustrated in the study, people are extremely sensitive to the extra work and burden involved in making lifestyle changes. Taking the individual's prior actions, personal likes and dislikes into account when providing suggestions would encourage easier lifestyle changes, as similarly found in (Rohani et al., 2020). In addition, while the availability of technologies such as ours makes it handy to do checkups, following some of the technologies' suggestions may be less easy, e.g., buying and cooking dietary meals. Integrating the technology with other applications or functions to show "how to cook" recipes or linking to places to easily order corresponding products are some ways to further reduce the workload of putting the advice into practice.

- It would be even better if health professionals could get involved, e.g., by making it incorporated into the general healthcare system, to help answer questions when needed, further ensure the validity of the health suggestions, and avoid some potential negative effects, e.g., the negative mindset of healthism (Crawford, 1980).

8.2. Dealing with the Complex Everyday Settings: Leveraging User Agency

With the continual development and advancement of computing technologies, it is to be expected that more intelligent health checkup technologies will become available for everyday use. They collect data with automatic and manual sensing technologies, employ Artificial Intelligence to analyze the health data, and provide assessment for our health or diseases (e.g., (Imran et al., 2020; Diethei and Schöning, 2018; Rana and Galib, 2017; Wang et al., 2018a; Mariakakis et al., 2017; Liang et al., 2020)). However, just as shown in our study, the incorporation of these intelligent checkup technologies, such as those that are camera-based, makes them more contextually sensitive. The tongue photo taking in our App, and oral images capturing in (Liang et al., 2020), are such cases where technically, the technology could be used anytime and anywhere, but is still constrained by other social factors and cultural norms. As pointed out by (Tse et al., 2004) and (Leidner and Kayworth, 2006), cultural and social factors, including trust, familiarity, contextual appropriateness, etc., have played an important role in determining the uptake and usage patterns of technology. The study also makes it clear how everyday settings are distinct from the well-controlled clinical environment; everyday settings are far more variable, dynamic, unpredictable, complex, and rich with cultural meanings that users need to take into account when putting such an intelligent technology into use.

The complexity of everyday settings is clearly manifested in the issue of accuracy, a common concern for AI-enabled technologies (Kao et al., 2018; Ding et al., 2019). A commonly explored solution is to increase the accuracy and accountability of AI-enabled health technologies, by algorithm-level optimization (Wei et al., 2020) or training the AI model with more samples from different real-world settings to improve its robustness (Tobin et al., 2017). What this study highlights is that accuracy is not merely a technical issue to be addressed with an engineering approach as is commonly believed, but rather, when taken into the space of everyday life, is instead collectively and dynamically shaped by various factors including the user's changing appearance (e.g., makeup, food coloring), the situated environment (e.g., lighting), and the ways users interact with the technology. Given the varied and dynamic everyday settings, providing context-awareness to adapt to different situations seems to be a sound solution (Kang et al., 2006). However, there is no ideal and easily predictable context, and sometimes the uncertainty of everyday settings is beyond our expectations. After all, context is not stable, but a dynamic and relational concept based on interactions (Dourish, 2004). In addition, users are not "cultural dopes", blindly following what they are told to do, but have their own methods of making sense of the setting and deciding what is appropriate (Garfinkel, 1964). In our study, user agency is clearly manifested in how our participants took advantage of the flexibility of the checkup steps, to fit it into various situations and meet their different needs. Some participants took various cultural and social issues into account, such as concerns about privacy, accuracy, visibility, and the accountability of the action, and strategically skipped steps. Some participants maintained comparable results for tracking by ensuring the same conditions for checkup.

Considering the inherently complex and unpredictable everyday context and user agency capabilities, then, probably, the more sensible approach is to leverage this agency, and let users take over control, make informed choices, and decide how to use the technology appropriately to fit into different settings. To support this agency, more flexibility in design may be a potential direction to explore, e.g., removing unnecessary constraints and inviting user participation in the decision-making process showing how factors might contribute to different results. Moreover, more transparency regarding technical agency, as well as the possible outcomes of certain user actions can be provided to further support the collective sense-making in technology use. Finally, the incorporation of more knowledge can strengthen the capabilities and health literacy levels of users, leading to the empowerment of user intelligence. This is to say, more intelligence does not mean more dominance of the whole process; as in our case, we can give increased control and freedom to users, through more flexibility, more transparency, more knowledge or other strategies, and let them decide how to use the intelligence to support their own ways of healthy living. Future work can explore the role of user agency in intelligent technologies, to what extent such agency may bring benefits or harm, and how to design to increase benefits and mitigate harm.

8.3. Enhancing Health Literacy and Sensitivity is the Key: Supporting Learning and the Reflective Process

In recent years, even though more data has been made available with the rising popularity of self-tracking technologies, they are primarily explored with the self-improvement (or behavioral change) framing; people's actual practice and lived experience of collecting, engaging, and reflecting on their data are often under-explored (Cosley et al., 2017). Reflection is considered central for people to learn more about themselves from the data and to find insight for future action (Li et al., 2010), and has attracted active research interest in HCI. However, as most of the data made available is quantified data, this has posed challenges for end users' engagement and how they make sense of the data, due to reasons such as the lack of quantitative analysis capabilities (Rapp and Cena, 2016).

Although our App was not specifically designed with reflection in mind, we found that users did not simply use the checkup to get their results, but engaged in it in a way to reflect on their health and lives. More specifically, they drew on the checkup process, the results, and the personalized and adaptive advice to think about their bodily experiences, their own likes and dislikes, and the causes of their health issues, to selectively take the technology's suggestions into their lives. We believe, quite different from other self-tracking technologies, which are characterized by quantified numbers and seem too abstract and disconnected from peoples' daily lives (Rapp and Cena, 2016), the use of qualitative and somewhat ambiguous descriptions of how their results manifest physically helped our participants reflect on their own life experience and gain awareness of how they truly feel. The quantitative approach, using charts, graphs, and statistical reports, sometimes can be hard to interpret and overwhelming (Daskalova et al., 2017; Lupton, 2013). In fact, research has found that such quantitative feedback can be a less effective way to foster reflection (Hinyard and Kreuter, 2007) and even have the opposite effect on health, potentially harming motivation and fueling negative mindsets that make healthy living seem stressful rather than desirable (Crum and Langer, 2007). Based on the study, we believe that for reflection, in addition to transparency and explanations scaffolding with related knowledge, a qualitative narrative description of their health status and personalized health advice will make it easy to engage users and invite reflection. Some features of Documentary Informatics (Elsden et al., 2017), such as allowing users to create personally meaningful journaling of their bodily experiences and linking it to the corresponding health assessment result, could also be helpful to further engage users in retrospective reflection (Ayobi et al., 2018).

We are particularly interested in reflection in that it is a process critical to people's internalization or learning of related knowledge and information that could lead them to effectively putting the advice into practice. As shown in the study, those participants who lived in a family with a Yang Sheng tradition showed more interest in using this kind of technology for everyday health, and exhibited more active, meaningful engagement in its use. It suggests that users who have already acquired necessary knowledge related to health, e.g., knowing their health statuses and understanding the effect of certain lifestyle choices, will more likely develop intentional and dedicated use of such technologies for self management. Reflection, as a personalized way to gain such related expertise, then, is crucial in designing for everyday healthy living. In the end, as suggested by our participants, it is through the enhancement of users' sensitivities and capabilities, and their own understandings of the correlations between their life choices and their health statuses, that they can put the advice into effective use on a daily basis. This awareness may have long-lasting effects on fostering reflection in daily life, increase users' sensitivities to aspects of life they previously neglected, and finally support their continual learning of health-related knowledge. Moreover, as suggested by our participants, we can support the reflective process even better by incorporating strategies, such as presenting the health assessment results in a more comparable way (e.g., by week or by month), supporting social comparisons (e.g., among family members), and situating users' situations against others' (e.g., the case of different tongue conditions).

9. Limitations and Future Work

Although the study is suggestive in terms of understanding the potential and design space of intelligent health technologies for everyday healthy living, we recognize that a 4-week field study is not substantial enough to show long-term effects in user behaviors. With intelligent health technologies becoming more available and more accessible for everyday use, it would be helpful to have more studies of this kind to explore its potential in supporting preventive health or everyday healthy living.

For future work on intelligent technologies for everyday health, it would be meaningful to provide timely feedback on progress through tracking capabilities. As the study revealed, everyday life interventions, such as dietary therapy and exercising, may be slow to take effect compared to medical interventions. Thus, it is not enough to just remind users to make efforts, but also important to show the effects of their efforts on their health to encourage users to persistently follow the suggestions. Although RegiBot does not have a dedicated tracking function, some of our participants utilized the checkup result to help track changes and assess the effects of their efforts over time. In that regard, future work can explore providing more explicit and dedicated tracking functions to support the regular and long term maintenance of one's health, e.g., allowing users to record their healthy life choices and showing comparable visual timelines. We will also make iterative improvements and further assessment on the underlying diagnosis model in the future.

10. Conclusion

In this paper, we investigated combining intelligent self-checkup technologies for overall health assessment and personalized lifestyle technologies to support everyday healthy living, through the iterative design of a mobile application based on TCM-based, AI-powered health checkup techniques. The field trial of an early prototype led to the design of a more adaptive, flexible and transparent prototype. Based on a field trial of such prototype, we highlighted how the temporal adaptability triggered corresponding usage patterns, how the flexible checkup process helped fit into complex everyday settings, and how the transparency as well as the qualitative narrative description supported the reflective process, which then potentially brought about behavioral and internal changes in the user. Based on our findings, we then suggested a number of design implications for intelligent health technologies to better support healthy living, including designing for regular maintenance, leveraging user agency to deal with the uncertainties in daily life, and supporting reflection and learning as of key importance to incorporate such technology into everyday health practices.

More importantly, this study suggests a promising design space for intelligent health technologies to address subhealthy issues and promote optimal health in an intelligent, convenient, and low-cost manner. Today, busy schedules in fast-paced lives leave little room for lay people to actively seek help from professional healthcare providers, and the already stringent medical resources make medical visits more of a burden and prevent people from actively seeking help more frequently. As such, minor issues may be easily neglected, leading us to be alarmed when diseases actually occur. The meaningful engagement uncovered in this study, including the regular periodic use, the deliberate control of environmental factors for comparable results, using checkups for meaningful reflection, making adjustments to life practices according to the technology's suggestions – and some having even seen positive health effects after following the suggestions for just a short period of time – leaves us cautiously optimistic that intelligent health technologies such as this one could have an important role to play in preventive health in everyday settings, or everyday healthy living.

CRediT authorship contribution statement

Yanqi Jiang: Conceptualization, Software, Investigation, Formal Analysis, Writing - original draft, Writing - review & editing. **Xianghua Ding**: Conceptualization, Formal Analysis, Writing - original draft, Writing - Review & Editing, Supervision, Funding Acquisition. **Di Liu**: Investigation, Formal Analysis, Writing - Review & Editing. **Xinning Gui**: Conceptualization, Formal Analysis, Writing - Review & Editing. **Wenqiang Zhang**: Software. **Wei Zhang**: Software.

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