Framing Self-quantification for Individual-level Preventive Health Care

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Abstract: Preventive health care is considered a promising solution to the prevalence of chronic diseases. Nevertheless, preventive health care at the population-level adopts an one-fit-all approach. We intend to solve the problem through promoting preventive health care at the individual level based on self-quantification. Nowadays millions of people are tracking their health conditions and collecting huge quantity of data. We propose a Preventive Health care on Individual Level (PHIL) framework that guides people to leverage their self-tracking data to improve personal health, which forms a data-driven but objective-oriented methodology. The PHIL framework consists of five phases: Define, Track, Analyze, Improve and Control (DTAIC), covering the whole process of a complete self health care project. While the proposed PHIL framework can be implemented to achieve various health benefit, we selectivelypresent one case study where the subject designed and conducted a self health care project for sleep quality improvement under the PHIL framework. We hope the proposed framework can help change the passive role of health care receivers in traditional health care system, and empower people to actively participate in the health care ecosystem and take the initiative in managing and improving personal health.

1 INTRODUCTION

According to a study on the causes of death (WHO, 2011), non-communicable chronic diseases, including diabetes, cardiovascular and respiratory diseases, account for two thirds of the death in 2011. As the population ages worldwide, complex chronic conditions will impose an even larger burden in the future (Mathers and Loncar, 2006). This represents a big challenge to traditional resource-constrained health care systems which are reactive in nature. In this regard, preventive health care could be a solution to the problem. Some preventive health services are already established or incorporated into primary health care, which has produced promising and encouraging outcomes (Group, 2012; Stieber, 2005). Nevertheless, existing preventive health care systems generally adopt the one-fit-all methodology and apply the same preventive measures to all people, ignoring the fact that a person could be distinctly difference from others (Mehl and Conner, 2012).

The self-quantification approach (Swan, 2013) offers a promising solution to the above-mentioned problem. Self-quantification has the potential to become valuable individual-level compensation to current preventive health care systems that are operated on the population level. According to a survey conducted by Princeton Survey Research Association International (Fox and Duggan, 2013), seven in ten US adults track at least one health metric and huge quantity of personal data is collected by individuals. Leveraging the self-tracking data, it would become possible for individuals to tailor their personal health management plans to their physiological conditions, which could be more targeted and effective than the one-fit-all measures in current population-level health care systems.

However, regardless of the great potential of the self-quantification approach, personalized self health care has not yet been widely adopted. The current scheme of self-quantification is centered on data collection, ignoring the rationality of what metrics to track in the first place and what to do with the collected data. Some self-quantification practitioners tend to test random ideas which are not medically proven to be associated; or someone have no idea what to do with the huge quantity of data they have collected. One of the main obstacle for individuals to conduct meaningful self-quantification projects is the lack of a framework that provides guidance on how to carry out the whole process.

In this paper we propose a general framework,

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named Preventive Health care on Individual-Level (PHIL), to facilitate individual-level preventive health care using self-quantification approach. The proposed framework intends to shift the methodology of self-quantification from data-centered to objective-oriented, and is centered on the idea that optimal outcomes from self-quantification occur only when the self-tracking data lead to concrete improvement actions, which represents a data-driven but objective-oriented methodology. This framework is inspired by a data-driven improvement tool called DMAIC (Pyzdek and Keller, 2014). Since managing personal health is an essential part of life-quality control, the DMAIC is a good reference for this research. The proposed PHIL framework has a five-phase cycle characterized as Define, Track, Analyze, Improve, Control (DTAIC). Each phase builds on the previous one, with the goal of sustaining long-term personal health.

The main contribution of this paper is the proposal of PHIL framework that serves as guideline for individuals to effectively improve personal health through meaningful self-tracking activities. The proposed framework aims at not only improving personal health but also saving cost for potential patients and society in general. The details of PHIL framework including the tasks need to be done and the tools that one can utilize in each phase will be described in Section 3. An example of the implementation of PHIL framework is presented in Section 4. Conclusions and future works are discussed in Section 5.

2 RELATED WORK

The self-quantification approach is originated from the Quantified Self movement, in which individuals self-track and collect data on various aspects in one's daily life, such as diet, physical activities, mood, blood glucose level, blood pressure, weight, etc. Data can either be logged manually or collected automatically using wearable sensors (Clifton et al., 2013).

In recent years, the advent of commercial sensing and mobile applications significantly automates the process of self-tracking. Many people track what they eat or how much physical activity they do every day, and huge amount of data are collected at the individual level on various aspects in personal life. Juniper Research (Juniper, 2013) estimated that users of mobile health devices may reach 100 million by 2018 globally, which is 6 times more than the number of current users. The sharp increase in the volume and variety of self-quantification data collected poses a big challenge to the management of these data. Efforts have been made on multiple aspects ranging from data integration (e.g. BodyTrack, Wikilife, Open mHealth), data classification (Almalki et al., 2014), to data management architecture (Whittaker et al., 2012) and standard (HL7, 2014). Using the tracking tools and data management platforms, some people have conducted their personal self-quantification projects with the purpose of gaining self-knowledge and improving personal health and wellbeing (Lewis, 2014).

Whereas data is a most indispensable component of a self-quantification project, data collection alone does not necessarily leads to health improvement at individual level. In reality, some self-trackers tend to test random ideas which are not medically proven to be associated; or someone have no idea what to do with the huge quantity of data they have collected. In this paper, we seek to address the above-mentioned problem and propose Preventive Health care on Individual Level (PHIL) to frame self-quantification for personal health care. The details on the proposed framework will be presented in the following section.

3 PROPOSED FRAMEWORK

The underline idea of the proposed PHIL framework is to guide individuals to first track the target health metric (e.g. sleep quality, blood pressure, blood glucose) and potential affecting factors (e.g. life habits, environmental factors, diet), then analyze the collected data to identify positive and negative affecting factors of the target health metric, make concrete improvement plan to strengthen the positive factors and eliminating negative factors, and finally sustain long term improvement. The five phases in PHIL framework, namely *Define*, *Track*, *Analyze*, *Improve*, *Control*, are described in details in the following subsections.

3.1 Define

The first phase in PHIL is to define the specific health metric that one seeks to improve, which lays the foundation for a data-driven self health care project. People can start with a reflection on personal life style with respect to diet, tobacco and alcohol consumption, exercise habit, etc. Based on the retrospection of one's life style, people can narrow down to a specific goal that they intend to achieve through a self-quantification project, such as losing weight, controlling blood sugar level, improving sleep quality, stabilizing blood pressure, to name a few. A good candidate metric should has the potential to result in en-

Table 1: Tracking and monitoring tools.

Categories	Devices & Mobile Applications
Sleep quality	Fitbit Tracker, Pebble, WakeMate, Lark, SleepBot, Zeo, Browzee
Physical activity	Fitbit Tracker, BodyMedia FIT, Jawbone UP, Nike+FuelBand
Diet & Weight	Fitbit Aria Scale, MyFitnessPal
Blood pressure	Actipressure
Blood glucose	iBGStar
Mood	Lume Personal Tracker, MoodPanda

hanced health conditions and has collectible data in order to achieve quantifiable results. In practice, target metric could either be a physiological metric such as weight, blood glucose, blood pressure, or a symptom such as headache, poor sleep quality. The target metric and the potential affecting factors form the set of variables that need to be tracked in the next phase. The target health metric is the dependent variable while the potential affecting factors are the independent variables.

In addition to defining the target metric and potential affecting factors, users also need to clarify the resources or budget available for the self-healthcare project, as this may limit the duration and the method of tracking in the next phase.

3.2 Track

The purpose of this phase is to track the set of metrics decided in the previous phase to collect sufficient data. These data will be used in the next phase to investigate the critical affecting factors of the target health metric. The data on the target metric also help establish a baseline which will be compared to the values of the metric at the end of the project to determine objectively whether improvement has been made. A data collection plan needs to be created to decide on how to measure the set of metrics. There is usually tradeoff between cost and convenience. One can either use wearable devices or mobile apps to automatically collect data or use spreadsheet to manually log the values. The former is convenient and efficient but purchasing and maintaining the devices could be expensive; the latter is an economic method but requires will power to persist the repeated work day after day. The currently available tracking and monitoring tools are summarized in Table 1. It is necessary to make sure the measurement tools can ensure sufficient accuracy and precision, as good data is at the heart of the proposed PHIL framework.

In addition to the tracking on the target metric and affecting factors, people also need to decide where to store the collected data. People can choose traditional local data storage devices such as computer hard disk, portable hard disk, flash memory (CNET, 2014). Storing data locally can ensure better privacy but requires much local storage space. Alternatively, people may also choose to store the data remotely using online data storage services based on cloud technology (JustCloud, 2014; MyPCBackup, 2014; Code42, 2014). Comparisons among different online storage services can be found in (HealthVault, 2014). Online storage can help save local storage resources and makes it easy to synchronize among multiple digital devices, but the merits are achieved at the sacrifice of weaker privacy and security. A combined approach using both local and remote storage is described in (Kampmeier, 2014).

3.3 Analyze

The purpose of this phase is to identify the gap between current and desired status of the target health metric, and extract insights from the data collected in the previous phase. The former can be achieved by plotting the histogram of the target health metric, while the latter requires applying data analysis techniques.

Since people may use different tools to track different factors, it is usually necessary to integrate the data from different tracking tools into one data sheet first. Missing values and wrong data should be cleaned out as well. The data cannot be used for analysis until it is integrated and pre-processed. Then people can apply analysis techniques to investigate the relationship between potential affecting factors and the target health metric, and seek out critical affecting factors. A common approach is to firstly identify a large number of potential affecting factors of the target metric and then select the top 3-4 correlated factors for further validation. Regression accompanied by statistical tests using p-values (Casson, 2011), Histograms, scatter plot (Utts, 2005), and factor analysis (Harman, 1976) are often applied to understand the magnitude of contribution of each affecting factor to the target metric. It is acceptable to use basic tools if these are appropriate. However, it is preferrable to use complex analysis tools are often used to gain deep understanding of the data, such as advanced data analytics, data mining, and advanced modeling. Various

statistics software tools are available to conduct data analysis and visualization, such as Excel, Statistica, Weka, R, to name a few. Note that it usually requires sufficient background in statistics in order to use the software.

3.4 Improve

The purpose of this phase is to identify, test and implement an solution to the problem. An improvement plan should be designed and improvement actions should be conducted. Improvement plan on lifestyle adjustment and behavior change should be based on the insight obtained from the previous phase.

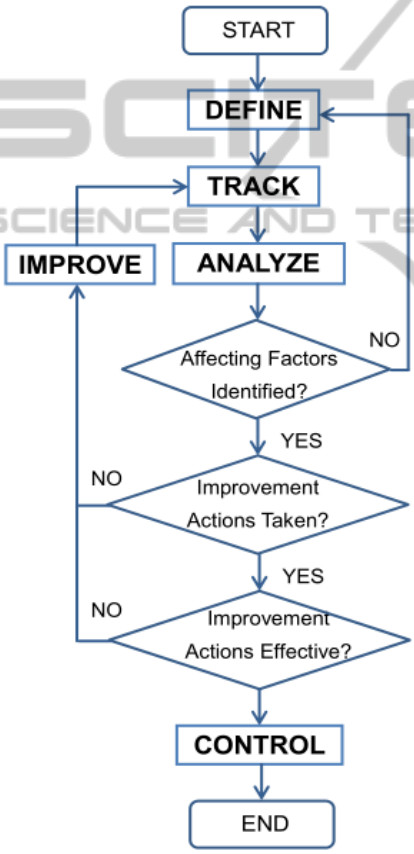

Figure 1: The workflow of PHIL framework.

It is possible to focus on obvious solutions if these are apparent, or else complex tools like DOE (Design of Experiments) (Shuttleworth, 2014) should be applied. For example, an iterative four-step management method PDCA (plan–do–check–act or plan–do–check–adjust) (Berengueres, 2012) can be applied to achieve continuous improvement.

3.5 Control

The purpose of this phase is to sustain the improvement. One needs to keep tracking the target metric to ensure continued and sustainable success. From psychological point of view, people need to be motivated in order to persevere their efforts throughout the potentially long ”Control” phase. Two methods can be applied: incremental goal setting and regular self-reward. Before starting the ”Control” phase, one can define an initial set of ”motivations” before starting a control plan, such as ”to be a best shape to attend my daughter’s wedding”, ”run next year’s half marathon”, ”maintain my weight at 60kg”, etc. A control chart can be useful during this phase to assess the stability of the improvements over time by not only serving as a guide to continue monitoring the target health metric but also providing a response plan in case the process becomes unstable. Statistical process control (SPC) (ReVelle, 2004) can be applied in complex scenarios if needed. Every time a small goal is achieved, one can have a celebration before setting the next new goals, e.g. go to the opera with best friend, buy a new dress, etc. Celebrating behavior change with rewards is the recognition of the achievement that one has achieved, which helps build self-esteem and boost morale to continue the efforts. This is very important in sustaining long-term improvement and maintenance of our health.

The workflow of PHIL framework is illustrated in Figure 1. Each of the five phases builds on the previous ones but the whole workflow is not necessarily sequential. Depending on the project, two types of sub-process cycle may be necessary in order to achieve meaningful outcomes. The cycle of DEFINE-TRACK-ANALYZE happens when the ANALYZE phase shows that none of the potential affecting factors is correlated to the target metric. In this case, one has to return to the DEFINE phase to redefine the potential affecting factors until critical affecting factors can be identified in the ANALYZE phase. This cycle lays the foundation for the following IMPROVE and CONTROL phases. The cycle of IMPROVE-TRACK-ANALYZE serves to validate the improvement plan; long-term improvement on the target health metric is impossible to achieve if the improvement plan is not effective in the first place. People may seek professional suggestions or advice from doctors and physicians throughout the whole process of a self health care project if they are not certain about the safety of the decisions they make.

Table 2: Summary of Five Phases in PHIL Framework.

Phase	Tasks	Tools
DEFINE	- Identify the target health metric. - Identify the potential affecting factors. - Clarify the resources of the project.	Brainstorming, literature review, Shewhart Chart, Check Sheets, Pareto Chart
TRACK	- Identify the tracking and monitoring tools. - Decide on data storage form and place. - Establish and validate data collection system. - Collect sufficient data.	Diaries, excel files, digital devices, mobile applications.
ANALYZE	- Integrate data from different sources if necesary. - Pre-process data to clean out missing value and wrong data. - Establish a baseline of the target health metric. - Identify the gap between current and desired status. - Apply data analytics techniques to identify critical affecting factors. - Prioritize critical affecting factors to pursue in the *Improve* phase.	Dashboard, Excel, Statistica, SPSS, R, Weka, etc.
IMPROVE	- Create and test the improvement plan. - Refine the improvement plan. - Create a detailed implementation plan. - Take improvement actions.	Brainstorming, literature review, decision matrix, DOE, PDCA, etc.
CONTROL	- Create a control plan. - Sustain the improvement on target metric.	Brainstorming, literature review, dashboard, etc.

4 AN EXAMPLE OF PHIL FRAMEWORK IMPLEMENTATION

The proposed PHIL framework is a general framework that can be implemented to achieve various health benefit for sickness prevention, such as weight reduction, blood pressure control, blood glucose control, to name a few. Due to the page limitation, we selectively present one case study in this section where the subject designed and conducted a self health care project for sleep quality improvement under the PHIL framework. The subject of this case study is a 25-year-old healthy Asian female with no medical history of any significant sickness or chronic diseases.

4.1 Define

The objective of this project is to improve sleep quality, which is characterized by two target metrics *Wake-Up Freshness (WUF)* and *Subjective Sleep Efficiency (SSE)*. The score of WUF ranges between 0-5 with 5 representing perfectly alert, while the score of SSE ranges between 0-5 with 5 representing deep sleep with no dream. Whereas there are various approaches to quantify sleep quality (Buysse et al., 1989; Thomas, 2012), we decide to avoid unnecessary complexity in this preliminary case study and designed a simpler scoring system which is summarized in Table 3.

We conducted a literature review to decide the potential affecting factors for investigation. The demographic variables, such as age (Doi et al., 2003), ethnicity (Stepnowsky et al., 2003), and gender (Vitiello et al., 2004), are not suitable for individual-level study because these factors cannot be changed in a person. In addition, there is no need to consider physical illness factors (Poelstra, 1984), as the subject does not have medical history of any significant sickness or chronic diseases. Furthermore, smoking and alcohol consumption (Philip and Danner, 1995) are also irrelevant factors because the subject does not have these habits. Based on the above consideration as well as retrospect of her lifestyle, the following variables are selected as the potential affecting factors for investigation in the *Track* phase. Note that for different people the potential affecting factors could be significantly different.

- Psychological status: stress and mood.
- Environmental conditions: noise and light.
- Lifestyle behaviors: caffeine consumption, electronic device usage before going to bed, physical activity level during the day, nap duration, dinner time, go-to-bed time, sleep duration of previous day, get-up time, level of tiredness.

Table 3: Defining target health metrics.

Score	Wake-Up Freshness (WUF)	Subjective Sleep Efficiency (SSE)
5	Very alert	No dream.
4	Alert	Being aware of dreaming but no memory of the content.
3	Fairly clear-headed	Being aware of dreaming and with blurred memory of the content.
2	Drowsy	Being aware of dreaming and clear memory of the content.
1	Very Drowsy	Nightmare.

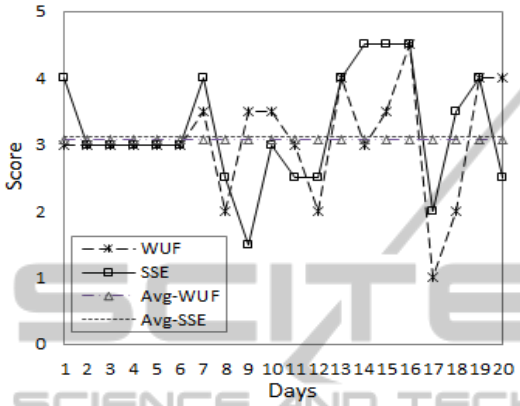

Figure 2: Time series of WUF and SSE over 20 days.

4.2 Track

The tracking of the variables were done in the form of a diary. The subject kept logging all the potential affecting factors and the target metrics on a daily basis and all the data were stored in an Excel file. The tracking last 20 days.

4.3 Analyze

In order to establish the baseline for comparison, we first plot the time series of both target metrics in Figure 2. The average values of WUF and SSE are approximately 3, which means the subject usually feel fairly clear-headed when she wakes up in the morning, being aware of dreaming and with blurred memory of the content. This indicates that there is much room for improvement.

We then investigated the correlation between each potential affecting factor and the target metrics. The results are presented in Table 4 and 5. We use the Pearson correlation coefficient (Pearson, 1895), denoted as r, to quantify the degree of correlation between each individual affecting factor and the target metric. Higher value of r represents stronger correlation. The p value indicates statistic significance, where $p < 0.05$ is considered statistically significant and $p < 0.01$ is considered very significant (Nuzzo, 2014). The top four correlated factors of WUF are the activity level during the day, the degree of exposure to light before going to bed, the get-up time and the caffeine consumption. The top four correlated factors of SSE are the nap duration, the get-up time, the body temperature before going to bed, and the usage of electronic devices before going to bed.

Table 4: Correlation between critical individual potential affecting factor and Wake-Up Freshness (WUF).

Factors	r	p value
Activity level	0.384	0.094
Light	0.310	0.184
Get-up time	0.230	0.328
Caffeine consumption	0.218	0.357
Nap	0.196	0.406
Tiredness	0.196	0.407
Noise	0.151	0.526
Body temperature	0.143	0.546
E-devices	0.131	0.581
Dinner time	0.129	0.586
Go-bed time	0.069	0.772
Mood	0.058	0.807
Stress	0.025	0.916

Table 5: Correlation between individual potential affecting factor and Subjective Sleep Efficiency (SSE).

Factors	r	p value
Nap	0.574	0.008
Get-up time	0.503	0.023
Body temperature	0.441	0.051
E-devices	0.378	0.099
Stress	0.274	0.241
Activity level	0.274	0.241
Mood	0.256	0.275
Dinner time	0.220	0.351
Noise	0.158	0.504
Go-bed time	0.098	0.682
Caffeine consumption	0.069	0.773
Tiredness	0.022	0.925
Light	0.013	0.957

4.4 Improve

In the previous phase, the analysis of the tracking data indicates that the nap duration has positive correlation

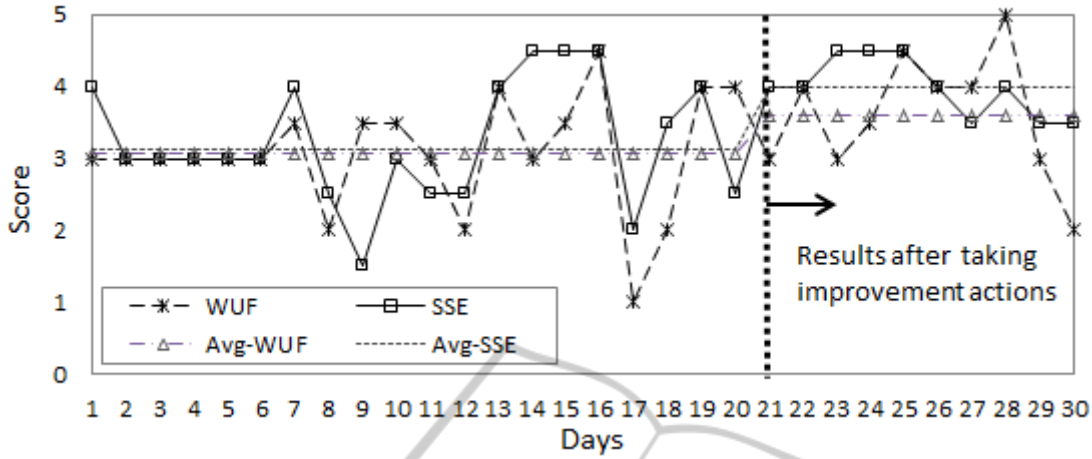

Figure 3: Results of SSE and WUF after taking improvement actions.

to SSE with strong statistical significance, while the get-up time is negatively correlated to both SSE and WUF with statistical significance. This finding suggests that taking a nap after lunch may help improve SSE, while getting up early in the morning may help improve both SSE and WUF. The subject did sometimes take a nap in the afternoon, but not on a daily basis. Besides, she reported that her get-up time was not regular, ranging from 6:00 to 9:00 a.m. without a particular pattern. Since the solution is very obvious in this case, it is not necessary to apply DOE and PDCA. By considering her daily schedule, the improvement plan included (1) taking a nap after lunch and (2) getting up before 7:30 a.m. The subject took improvement actions from the 21st day on until the 30th day.

4.5 Control

The results of SSE and WUF after taking improvement actions is illustrated in Figure 3. It shows that the SSE has been substantially improved with the average score increasing from 3 to 4 after the subject took improvement actions. The deviation of SSD is also reduced, which infers that the SSD is under good control. As to the WUF, the average score is increased from 3 to 3.5, though the daily score is not as stable as that of SSE. Since the results are encouraging, the subject has the confidence to secure the improvement by maintaining the improvement actions of taking a nap after lunch and getting up before 7:30 a.m. in the morning.

5 CONCLUSION AND FUTURE WORK

In this paper, we have proposed a framework named PHIL for individual-level preventive health care in the context of self-quantification. The proposed framework intends to shift the approach of self-quantification from data-oriented to objective-oriented, aiming at not only improving personal health but also saving cost for potential patient and society in general. The PHIL framework consists of five phases: Define, Track, Analyze, Improve and Control (DTAIC). Each phase builds on the previous one, with the goal of sustaining long-term personal health. A example was provided on implementing the PHIL framework to improve personal sleep quality of a healthy Asian female. Although this case study is preliminary in nature, it is sufficient to illustrate the implementation of the PHIL framework.

The PHIL framework is a general framework that can be implemented to achieve various health benefit, such as weight reduction, blood pressure control, blood glucose control, to name a few. Providing that many individuals actively implement the PHIL framework to improve various aspects of their health conditions, not only people's health can be improved at the individual level, but also the aggregated health of the whole population can be substantially improved and thus public health cost can be reduced. In this regards, the PHIL framework can benefit both individuals and the government.

In the next step, we intend to develop an online self health care system that people can use to implement the PHIL framework, which can be accessed by all Internet users regardless of their physical loca-

tions. This system will cover various critical aspects of personal health, including sleep quality, weight, blood pressure, blood glucose, mood, etc. We will collect feedback from the users based on which extensive evidence-based study will be conducted to verify the effectiveness of this framework.

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