Hypothesis evaluation based on ubicomp sensing: moving from researchers to users

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Abstract. Emerging pervasive sensing technology provides new ways to create persuasive systems that can help people improve their health. Much persuasive computing research has involved the exploration of *researchers*' hypotheses about the ways that such ubicomp sensing can improve health. Our work aims to enable individual users to test their *personal* hypotheses about how their actions, as tracked by ubicomp sensors, and the interface tools that they elect to use, actually impact their health goals. This paper defines the notion of personal hypothesis evaluation. It then outlines a ubicomp architecture for the infrastructure and interfaces needed to enable a person to formulate a personal health hypothesis and then test it over a long time period, weeks, months or even years. Our key contribution is the definition of a new approach to creating a new class of user-controlled ubicomp persuasive system.

Keywords: Persuasive technology; ubiquitous sensing; personal health hypothesis; hypothesis evaluation; personal informatics.

1 Introduction and Related Work

A hypothesis is "an idea or explanation for something that is based on known facts but has not yet been proved"[1]. It is also defined as "a proposition, or set of propositions, set forth as an explanation for the occurrence of some specified group of phenomena, either asserted merely as a provisional conjecture to guide investigation (working hypothesis) or accepted as highly probable in the light of established facts"[2]. This paper defines a *personal health hypothesis* as an individual's belief about the ways that their actions affect their health. For example, a person may believe that if they significantly increase their level of physical activity, this will improve their health, in line with current health recommendations [7]. Other examples include: '*If I eat less fat and oil, I will be healthier*' and '*If I restrict my consumption of carbohydrate, I will loose at least the rate of 2 kg in 8 weeks*'.

[1] http://dictionary.cambridge.org/dictionary/british/hypothesis?q=hypothesis
[2] http://dictionary.reference.com/browse/hypothesis

A large body of persuasive and ubicomp research has explored research hypotheses related to improving or maintaining health. For example, the seminal work of Consolvo et al. [4] studied effects of UbiFit on the level of activity people maintained. UbiFit is an exemplar of a ubicomp sensor based system designed to improve health. It provided glanceable display on the users' phone, enabling them to notice, or regularly check, their recent levels of activity. Essentially, that work evaluated the *researchers*' hypothesis that people achieve and maintain higher activity levels in the long term if they can readily see how active they have been recently. Li et al. [14] explored of various forms of personal data to improve awareness of physical activity. There has been considerable research evaluating various hypotheses about the ways that tracking individual's data affects a behavior, an attitude or both (such as [4], [2], [12], [16]), but personal hypothesis evaluation, based on the individual user setting and testing their own hypotheses, has not yet been considered.

People do not have complete knowledge about themselves and the factors that affect their lives [17]. New technology and emerging ubicomp sensors makes it easier for them to collect their personal data. This creates the possibility for people to use this data to track aspects of themselves that would otherwise be hard to measure. If they are trying to change a behaviour, such as doing inadequate levels of exercise, these sensors and associated displays enable them to see whether changes they make in their behaviors appear to result in an improvement they want to achieve [15]. Our work is similar to these systems in terms of the sensors and displays that are relevant. However, in our work, we want to make it possible for the users to define their own hypotheses. Essentially, we aim to create an opportunity for a person to take a new form of control over the ways that they make use of ubicomp sensor technology to help achieve their health goals.

2 Defining Personal Health Hypothesis

As a foundation for defining our approach, we introduce an illustrative scenario.

Alice has just been diagnosed with mild hypertension (high blood pressure). She decides she wants to try altering aspects of her lifestyle to tackle this. She has been given an overwhelming amount of literature and advice. This points to several possible hypotheses about reducing hypertension. She decides she would like to test the hypothesis: if I exercise more that will reduce my blood pressure.

Alice might buy an activity sensor device[3] to track her activity levels, and a device to measure her blood pressure[4]. These ubicomp sensors could collect the data required to evaluate her hypothesis in the scenario.

We now can define the elements of a *personal wellness hypothesis* that can be assessed by a ubicomp sensing system.

[3] for example, a FitBit http://www.fitbit.com

[4] for example, a Withings Blood Pressure Monitor http://www.withings.com/en/bloodpressuremonitor

1. The user must formulate a suitable hypothesis. It takes the form if I do X then I will see effect Y over time period Z.
2. X and Y can be measurable by ubicomp sensors (potentially multiple sensors for each).
3. The user must establish the baseline values for X and Y.
4. The user must set appropriate goal values for X and Y.
5. The user must make use of the devices to measure X and Y over time period Z, making use of interfaces that are based on best practice for persuasive technologies.

We now illustrate this in terms of our scenario. Suppose Alice sets the hypothesis: *If I increase my level of activity, my blood pressure will drop.* Armed with her FitBit, she can easily collect long term data that measures at least some aspects of her activity. Her starting point for assessing her hypothesis is to establish her baselines for X (activity level) and Y (blood pressure). To get the baseline, she should use the FitBit for a period of time, such as a week. For example, this may indicate she typically walks 5,000 steps a day on work days and 15,000 a day on weekends. Similarly, she can use the Withings device to measure her blood pressure. This also needs to be done over a period of time. This is because a single blood pressure reading is not a reliable indication of her true blood pressure. So, she may take the early morning and evening measures each day for a week [19]. She then needs to decide a suitable time period to assess her hypothesis (Z). For example, she realizes that it may take several weeks for a change in activity to affect her blood pressure. So, she may select Z as 6 months. We note that persuasive literature (e.g. [3], [4], [5], [6]) indicates that she will benefit from feedback through that period. Such support can be readily provided by a ubicomp based system. At the end of the period, she will need interfaces that help her assess whether her hypothesis was supported by the evidence. This means that she needs to be able to see if she did indeed increase her level of activity and maintain that increase during the 6 month period. She also needs to get a measure of her blood pressure at that time, following a similar process to that used to determine the baseline.

Although we illustrated our definition in terms of our scenario, personal hypothesis evaluation can be applied much more broadly. For example, it could make use of other sensors, even for this hypothesis. There are also many other ubicomp sensors[5] that could support other hypothesis involving, for example, weight, intensity of activity and glucose response. There is also considerable scope for people explore hypotheses about other aspects of their lives, such as altering behaviors to reduce carbon footprint.

In our work a personal hypothesis is intended for an individual person. This is quite different from scientific hypotheses that are intended to be general, applying to large populations. Even these are often statistical or stereotypes [8] [20] that do not actually apply for *every* individual. For a personal hypothesis,

[5] For example, Withings Body Scale http://www.withings.com/en/bodyscale to measure weight and fat mass, Basis https://mybasis.com/ to track heartbeats, BodyMedia http://www.bodymedia.com/ to track calorie burned.

we are concerned with one participant, the individual person who wants to test the hypothesis. Therefore, despite the broader definition of a hypothesis, we will not deal with population level outcomes. We aim to provide a framework and the required interfaces, which make it possible for an individual to define, formulate and evaluate a personal hypothesis.

We believe that our approach may be valuable if evaluation of a personal hypothesis encourages individuals to be creative and out their own approaches to achieving their goals. But this assumes people would like to use such systems in order to collect their personal data and test their hypotheses. We have some indicators that this is so. There is an increasing number of ubicomp devices to track different aspects of individuals, a growth of number of systems being developed for this purpose and lots of research about self-monitoring, self-reflection, goal-settings and controlling personal data (such as [18], [16], [9], [13]). This suggests that people would like to collect their personal data, use available ubicomp sensors for this purpose and monitor the effects of their actions on the stored data over the long term. These kind of systems help people to collect, explore and reflect on the information; our work adds a way to think about this data.

Quantified Self [6] is a movement which brings together the users and tool makers interested in self-tracking systems to share their knowledge and experience. People share the lessons they have learnt and the tools they have used in their experiences. This community shares different individual's self-tracking projects in their gatherings and they learn from each other. These projects concern many different aspects such as health, citizen science, sustainability and personal life styles. Our personal health hypothesis evaluation, reflects the spirit of many members of the Quantified Self movement which exploits technology to collect personal data in order to test a hypothesis.

3 Proposed Architecture

The proposed architecture for hypothesis evaluation is shown in Fig. 1. A set of data based on the ubicomp sensing would be collected via the *Sensors*. *Users* control the system using *Personal Hypothesis Setting*, *Sensor Linking* and *Personal Hypothesis Evaluation* user interfaces.

Personal hypothesis setting is based on its form 'if I do X then I will see effect Y over time period Z'. The three parameters of X, Y and Z are needed to be set using the personal hypothesis setting user interface (Fig. 1.b) and the values of X and Y will be collected over time period Z. For example, the parameters in our scenario's hypothesis are activity level (X), blood pressure (Y) and 6 months (Z).

To create user models and hypothesis, personis [11] will be used. This generalised framework has the power, flexibility and low cost for implementation and supports privacy and scrutability (means that users know which information are personalised for them and how the system decides to select them)[1], [10].

[6] Quantified Self website: http://quantifiedself.com

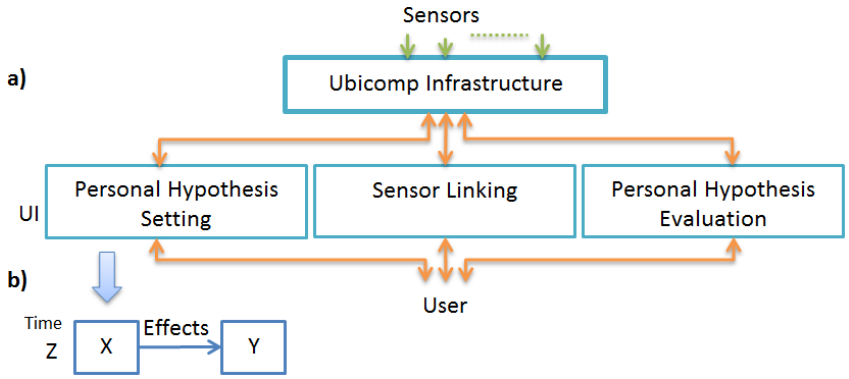

Fig. 1. a) Proposed Architecture, b) Personal Hypothesis Setting.

4 Conclusion

Our key contribution is defining a new approach of personal informatics based on ubicomp sensing to achieve long term goals such as being healthier. We have proposed an architecture to create a new class of user-controlled ubicomp persuasive system to support personal health hypothesis evaluation. Our next steps are to implement this infrastructure and assess how people use it.

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