THE IMPACT OF HCI DESIGN ON HEALTH BEHAVIOR: THE CASE FOR VISUAL, INTERACTIVE, PERSONALIZED-CONTENT (VIP) FEEDBACK

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Abstract

There is overwhelming evidence of patients’ low compliance with taking medication and keeping health related diets. In this work, we explore Visual, Interactive, and Personalized-content (VIP) feedback, as a novel method for increasing a patient’s compliance with health care prescriptions. We hypothesize that VIP feedback positively affects intentions to change health behavior by affecting the users’ sense of involvement, self-efficacy and comprehension, and, thereby, affecting their intentions to change behavior. We then test the mediation model through a longitudinal experiment in which the subjects used a nutritional information system that supplied them with personal medical information (n=155). The results support the mediation model and present interesting implications for design. VIP feedback offers an opportunity to develop long-term intervention effects on users’ behavior.

Keywords: Feedback, Visualization, Personalization, Interactivity, Self-efficacy, Health Behavior
Introduction

Consider the following common situation of a patient sitting in front of her doctor, waiting to hear the diagnosis. "The results are not good. Your blood pressure is too high and your physical condition very poor. Look at this chart of blood pressure categories and heart failures. You are in this red category, Hypertension. If you don't take action, you will die early. I'm putting you on 81mg Aspirin you take every morning when you wake up. Additionally, you must cut down salt and fat. Make an appointment with the dietary unit here in the hospital – they will give you a list of foods you are to avoid. Do you have any questions?" "Yes, one. I'm off with the family to Disneyland next week. Is that OK?"

Patients listen to what their doctor has to say but often do not comprehend and frequently do not adhere. There is overwhelming evidence of low compliance in taking medication and keeping health related diets (van der Wal et al., 2006). The dialog above is not effective even though it seems comprehensive, including a clear statement of the problem, the consequences and the necessary action. The dialog is not effective because the patient listens passively, looking at what she hears from her own perspective. Furthermore, computer-mediated communication between patients at home and doctors in the hospital is likely to intensify noncompliance with health care prescriptions (Wang et al., 2002). Already, more patients in more countries are expected to spend less time than before in consulting face-to-face with their medical care givers (Dugdale et al., 1999; Gulbrandsen et al., 2012), relying increasingly on Internet-based systems, with or without human intervention, to advise, support, monitor and report self-managed health behavior (Lau et al., 2012; Rosser et al., 2009). However, if these computer systems fail to improve the communication with patients, they may lead to even lower compliance than currently experienced and result in poorer health.

The research question we ask here is whether the human-computer interaction (HCI) of these systems can be designed so as to positively affect a patient's compliance with health care prescriptions. The context of this research is a design research project in which we explore a particular form of feedback to patients self-managing their health problem. In this paper we concentrate on the impact of the HCI design on health behavior. Compliance for lifestyle changes is as low as 30% of chronically ill patients (Vermeire et al., 2001; Haynes et al., 1979), and compliance is especially low in cases that require changes of existing habits (Chesney, 2000).

Our model attempts to represent several aspects of human behavior that affect compliance that involves changing behavior, not only of ill patients but of health information consumers, in general. Following recent HCI research on designing representations, we complement the cognitive view of human behavior with affective and attitudinal aspects (Davern et al., 2012). In the case of compliance, patients must not only understand why and what needs to be done but they must believe they can do it. Health behavior promoting interventions like bicycle helmet use (Witte et al., 1993), nutritional behaviors about osteoporosis prevention among students (Ghaffari et al., 2012), alcohol consumption (Murgraff & McDermott, 2003) or unhealthy eating habits (Satow & Schwarzer, 1998) emphasizes the importance of self-efficacy as a cognitive mediator of action. Finally, compliance is determined over time so that the impact of the HCI must be lasting and tied to intrinsic motivation. This aspect also has implications on research methods. While instant reactions and instant attitudes have become an important topic of HCI research, evaluating HCI for longer term behaviors such as health care compliance requires longitudinal studies.

Online feedback is a good candidate to impact the multiple aspects of human behavior. Furthermore, it is also a pivotal dimension of HCI for complex tasks, and in particular a critical component of any health care system to support self-management. This paper focuses on a form of feedback we believe can lead to higher compliance with recommendations in general, and medical prescriptions in particular. We call it Visual, Interactive, Personalized-content (VIP) feedback. In this paper we explain the design rationale for VIP feedback by looking at how the design impacts the patient's cognition and affect (represented by comprehension, self-efficacy and involvement) and how cognition and affect impact the patient's intentions to change behavior. The model is depicted in Figure 1. We test this model in an experiment using a personal web-based information system we developed for the experiment. The results demonstrate our contribution to the fields of Health Information Systems and HCI in understanding the
combined effect of the elements of VIP feedback on intentions to change health behavior through the mediating variables.

**Theoretical background**

In order to design for changing health behavior we build on theories of behavior and theories of comprehension and learning (Chi, 2009; Papert & Harel, 1991). Designs that afford compliance are firmly anchored in theories of behavior, ranging from stage models like the Stages of Change model (Prochaska & DiClemente, 1984) to social cognition models, such as the expectancy-value theory and its extensions (Fishbein & Ajzen, 1975; Ajzen & Fishbein, 1980; Ajzen, 1985) and the Self-efficacy Theory (Bandura, 1997). These theories of behavior have already been used successfully in the context of changing health behavior, e.g., the Health Believe Model (Janz & Becker, 1984; Rosenstock, 1974) and the Health Action Process Approach model (Schwarzer, 1992).

We begin with the three elements of VIP feedback. Visualization is the visual representation of information to convey its meaning, e.g., visually showing the dynamics of variables and the relationships among them (Chen, 2005). Interactivity allows users immediate control and feedback in their interactions, e.g., the "What if" mode of interaction (Steuer, 1992). Personalized content is the adaptation of general information to the personal information of the particular user, e.g., showing a drug’s recommended doze according to the user's height and weight rather than according to population averages. VIP feedback is the design of feedback that incorporates all three elements. For this study, we operationalize the level of VIP feedback as the extent to which all three elements are present. In particular, feedback with only visualization and interactivity (VI) will be inferior to feedback incorporating all three elements (VIP) but superior to Personalized-content only (P). As elaborated below, these elements are not independent of each other. For instance, visualization and interactivity interact to produce a higher impact. We therefore define VIP level as an ordinal variable: VIP>VI>P (see upper part of Table 1 for definitions of these terms).

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visualization</td>
<td>Visualization is the visual representation of information to convey its meaning.</td>
</tr>
<tr>
<td>Interactivity</td>
<td>Interactivity allows users immediate control and feedback in their interactions.</td>
</tr>
<tr>
<td>Personalized-content</td>
<td>The adaptation of general information to the personal information of the particular user.</td>
</tr>
<tr>
<td>VIP level</td>
<td>The level of Visualization, Interactivity and Personalized-content embedded in the feedback, operationalized as an ordinal value of the variable: 1=P, 2=VI, 3=VIP</td>
</tr>
<tr>
<td>Comprehension</td>
<td>Understanding the content represented and its relevance to action.</td>
</tr>
<tr>
<td>Self-efficacy</td>
<td>People's beliefs in their capabilities to exercise control over their own functioning and over events that affect their lives.</td>
</tr>
<tr>
<td>Involvement</td>
<td>Involvement is the level of physical, cognitive and affective participation in some activity.</td>
</tr>
<tr>
<td>Intention to Change Health Behavior</td>
<td>The intention to behave in a certain manner as a basis to forecast behavior.</td>
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Research Model, HCI Design Rationale, and Hypotheses

Figure 1 shows the path from the design variable, level of VIP feedback, through the mediating variables comprehension, self-efficacy and involvement, to the intentions to change health behavior in compliance with given recommendations. Hypotheses 1-3 are the design rationale. Hypotheses 4-6 predict the impact of the design on behavior.

HCI Design Rationale

Think of a health information consumer, a healthy person who has been told to change her diet in order to stay healthy or one that has already shown symptoms such as high blood pressure, using a computerized system to build a health diet. The nutritional information system can be used to record actual daily food consumption, plan future diets and help maintain a routine of self-administered blood pressure tests. The user can experiment with alternative diets (e.g. choose different food items in the personal daily menu in a "What if" manipulation) and learn about the relations between food and health using her recorded data (e.g. blood pressure plotted against sodium intake). The system's design should encourage a change in the user's dietary habits towards the desired target behavior (Lockton et al., 2010). But here we go one step further, and design for the holistic experience involved in the ongoing process of reaching the target behavior. To this end, the system supports three aspects of the user's activity: it explains the connection between sodium (salt) consumption and blood pressure (this is the Comprehension), it provides the user an opportunity to be active (Involved) in the process, and it provides the user the conditions to build the confidence in her ability to self-manage her health condition (Self-efficacy). Our design goal is therefore to holistically support all three aspects (O'Brien, 2010; Hassenzahl & Tractinsky, 2006; Mahlke, 2005).

VIP feedback provides a dynamic and visual demonstration of the impact of a user's food consumption. The feedback presents short-term consequences of the recommended behavior which appear to the user as tangible and specific risks, e.g., the short-term results of low-sodium consumption (Morris & Halperin, 1979; Blackwell, 1976). Furthermore, the feedback is generated in response to the user's action (Renaud & Cooper, 2000) and depends on the user's personal data and needs. We now explain each of the three components of VIP feedback, building on a pilot study in which we tested separately the components by questioning users and observing their body behavior to determine when they better understood the information and when they seemed more involved (Authors, 2011).

Figure 2 depicts the VIP feedback screen. It consists of three rectangle areas: the leftmost describes food preferences, the middle rectangle shows a vertical bar chart with sodium consumption divided to home cooked food versus industrial food, and the rightmost rectangle shows a graph of estimated blood pressure over time.
We claim in this study that the combined impact of VIP feedback is particularly potent. Together with the immediate visual effect of the relationships between factors, VIP feedback creates a special learning environment while explaining the effects of the users' actions on their health (Balzer et al., 1989; Kerren et al., 2007). Interactivity enables the fast processing of which our cognition is capable by removing the data barrier (Norman & Bobrow, 1975) and the image based processing in visualization removes the barriers of sequential processing characteristic of textual processing. Thus the combination of visualization and interactivity is more than the sum of the two. Users are involved by creating or manipulating instead of merely watching or consuming (Shedroff, 2000).

Finally, Personalized-content, beyond its contributions to learning and motivation, leverages the impact of VIP feedback by extending the cognitive resources (Hudlicka, 2003). All in all the combination of visualization, interactivity and personalized-content is hypothesized to impact comprehension, self-efficacy and involvement.

The impact on comprehension

**Comprehension** is defined as understanding the content represented and its relevance to action (Te'eni, 2001). In an action oriented situation, the target behavior or the analysis of the context around it becomes the focus of attention in communication. Piaget (1978), for example, discusses comprehension as the 'how' and 'why' of relationships as applied in action. Due to the interactive nature of VIP feedback the users take part in the process of building their own knowledge. According to Papert & Harel's (1991) theory of meaningful learning the process of building new knowledge is more efficient when the learners are busy building a product which is realistic, personal, and meaningful to themselves or to their surroundings. This leads to the term constructivism which is often used to describe discovery based learning. The contrast is between passive learning from an instructor versus active learning during a self discovering process (Löfström & Nevgi, 2006; Chi, 2009).

Interactivity makes it possible to change properties and immediately see the effects, which is critical for learning in many contexts (Guzman et al., 2006). Importantly, interactivity does not only clarify relationships but also motivates the users by increasing their level of involvement in the activity. VIP feedback encourages the users to actively act on their own data through "what if" manipulations retroactively and as many times as they desires. While rehearsing correct nutrition decision making, the user benefits doubly by understanding the effect of changes on medical symptoms and by practicing the
target behavior. The advantage of VIP feedback's interactivity is that by using direct manipulation and embedding visual feedback in the user’s action in a natural way, the explanation of cause and effect is immediately seen without seeking it. Mouse hovering above alternative food items at the left side of the screen lets the user see at a glance the immediate visual change in the estimated blood pressure shown on the right side of the screen (See Figure 2). The visual change is perceived without the effort needed to compare the exact figures of sodium reduction. The strong impact made by the insight of the ease of change and the profitability of being active are created thanks to the unmediated dialogue between the user and the system as enabled by interactivity and direct manipulation. Direct manipulation is more playful, makes the learning experience more positive and encourages curiosity and investigation followed by personal success (Shneiderman & Plaisant, 2010).

This is exactly where the relation between comprehension and visualization has its optimum and concrete power. The role of Visualization in VIP feedback is providing in the most simple and observable way the results of changing health behavior. The unique combination of seeing the cost and affect of a certain result leads to the overwhelming insight or discovery which provides comprehension without words while consuming minimal cognitive resources (Ham & Midden, 2010). In HCI literature, insight is sometimes defined as the “purpose of visualization” (Card et al., 1999), the ultimate goal by which successful representations and interactions should be measured.

The dotted line on the graph which appears constantly displays the dynamically growing gap between previous graph location and current location. Again, it explains without words or calculations the amount of sodium reduction needed to affect a certain decrease of blood pressure values and the target goal. Personalized-content has great impact on comprehension. The target behavior is personal so that understanding the content in relation to one's own target behavior is part of comprehension. Indeed the context is all important in the process of comprehension (Kintsch, 1988). Personalized-content incrementally allows a person to **comprehend** information and **relate** it to himself, both at the same time with no extra effort.

While the information in Figure 2 could be general information that presents average users or certain stereotypes, the VIP feedback system describes the user’s personal information. When the user manipulates directly the personal data, the feedback is tied to the specific user's performance level and makes the feedback meaningful (as described in Hodges, 2004; Song & Keller, 2001). The user learns a medical rule as it is applied to the user's own medical and nutritional information. Personal information is more concrete and relevant, and therefore easier to understand and relate to (Keysar et al., 2000). The content is relevant to the users: they are usually overwhelmed by the total amount of their daily sodium consumption displayed by the information system, and also see the relationship between their own eating habits and their health condition.

Therefore we hypothesize that:

**H1.** A higher level of **VIP feedback** will be associated with higher levels of **comprehension**.

**The impact on Self efficacy**

**Self efficacy** is defined as "People's beliefs in their capabilities to exercise control over their own functioning and over events that affect their lives" (Bandura, 1997).

Interactivity affect of self efficacy relies on the users’ experience. This theory assumes that the sense of efficacy to perform a certain task is developed from previous experiences of the persons themselves: a positive previous experience will develop expectations to succeed in similar tasks in the future (Bandura, 1997). During the "What if manipulation", the users experience an actual personal menu change and succeed in reducing the level of sodium to the permissible level and also succeed to affect blood pressure values. This experience relates to Fishbein and Ajzen's Expectancy-Value Theory (1975), which discusses the users’ belief they can achieve it, and accomplish expectancies of goal achievement. Problem-solving skills and ability to make action plans are core features of self-efficacy (Chan et al., 2013). Furthermore, the visualization which is constantly showing the level of goal achievement contributes to the feeling that the goal is achievable.

Personalized-content contributes to self efficacy by providing personal preferences, alternatives or
solutions. As mentioned earlier, the users' personal data are used to display and demonstrate the general medical principle of the correlation between blood pressure and sodium intake. There is also value in the fact that the proposed solutions and nutritional alternatives are not presented from a general list the dietician suggests to all users, but the system shows the users a wide variety of food items that are personally relevant to them, depending on their taste and habits. The users can select food items that are best for them and their habits, and they don't get the feeling that there's no available solution for them, just because the dietician's general list of food items is for the general public and does not contain their favorite food items.

Therefore we hypothesize that:

**H2.** A higher level of VIP feedback will be associated with higher levels of self-efficacy.

**The impact on Involvement**

**Involvement** is the level of physical, cognitive and affective participation in some activity. In IS, involvement has been used extensively in connection with participation in systems development (Barki & Hartwick, 1994). Higher involvement implies greater Personalized-content and consequences than lower involvement (Petty et al., 1983).

Visualization affects sense of involvement in our unique experience by providing a type of trigger which calls for action. Visual constant yet dynamic display of the results of actions and the immediate feedback (unlike feedback in delay) triggers and encourages further playing with nutrition changes, waiting to see the results.

Interactivity affects sense of involvement by the way it triggers the user to act and become an "active user". Shedroff (2000) describes interactivity as an experience in which users participate by "creating or manipulating instead of merely watching or consuming". It is likely that by activities, users become more engaged with the learning materials than by not doing these activities (Chi, 2009). Shedroff (2000) emphasizes that if users are given the opportunity to be involved in the creation of something it may give them a sense of involvement and ownership which will make the process more meaningful.

Personalized-content eases and improves learning but also triggers emotions around the learning and its implication for action (Cordova & Lepper, 1996). Personalized-content affects sense of involvement as the users learn a principle medical rule from their own personal relevant detail. The medical and nutritional information is personal information, concerning true data of the users themselves. As in visualization, it triggers the users to further explore the result of their action on their personal data and to see what might be the effect of certain personal decisions regarding personal nutritional choices.

Therefore we hypothesize that:

**H3.** A higher level of VIP feedback will be associated with higher levels of involvement.

**Intentions to change health behavior**

Intentions to act are determined by attitudes and subjective norms (Ajzen & Fishbein, 2005). IS research employs extensively the intention to use a system. Here we ask the users about their intention to engage in their health behavior, which is supported by using the system.

The next three hypotheses define the relationships with Intentions to change health behavior. Ajzen and Fishbein (1980) originally proposed their theory of reasoned action to explain how attitudes and subjective norms determine intentions, and how intentions predict behavior. McCaul et al. (1993) extended the theory to include self-efficacy in order to predict health-protective behavior. They drew on Bandura (1977) to claim that users’ belief in how capable they are to perform the planned behavior will also predict intentions. Indeed, Ajzen and Fishbein (2005) proposed their theory of planned behavior for the very same reason, i.e., to account for behaviors that are not fully controllable. We consider change of health behavior to be such a behavior.

In a similar vein, we argue that understanding the reason for a certain behavior, its impact and how to perform the behavior is necessary for successful behavior change but is not enough (as suggested by the
opening dialog between doctor and patient). Studies have demonstrated that understanding the information and its implications is necessary but not sufficient to change health behavior (Funnell & Anderson, 2000; Mazzuca, 1982). Although people comprehend the problems and risks of lack of treatment, the problem of implementing knowledge and persistence over time still remains (Blanson-Henkemans et al., 2009).

Involvement is important exactly for this reason. Intentions that are derived from internal feelings and motivation are regarded as more effective than those of patients who are dependent on external professional agents (Prochaska et al., 1994). Patients who have been involved in the decision-making process are more likely to have a greater intention to adopt or change a behavior than patients who have simply been told to make a change (Cole & Kern, 2006). Using their theory of central and peripheral persuasion, Petty et al. (1983) offer an explanation for the effect of involvement: in situations of high involvement, the change of attitude occurs in the central route, which is characterized by diligent consideration of information. And importantly, the effect of attitude change in the central rather than the peripheral route is that relatively enduring and predictive.

Hence, the following hypotheses are rendered:

H4. Greater Comprehension will be associated with stronger Intentions to change health behavior
H5. Greater Self-efficacy will be associated with stronger Intentions to change health behavior
H6. Greater Involvement will be associated with stronger Intentions to change health behavior

Research Methodology Design

Apparatus, Sample, and Procedure

For this research project, we conducted an experiment using a nutrition information system we developed, intended for healthy users who wish to manage a low-sodium daily menu, in order to avoid high blood pressure (see Figure 1 above). The healthy public is usually not aware of the need to reduce sodium intake, in order to prevent high blood pressure. High blood pressure is called the "silent killer" because often it has no warning signs or symptoms, and many people don't realize they have it (Centers for Disease Control and Prevention, 2009). People are not aware of the amount of sodium they consume. Healthy people should get no more than 2,400 mg per day (about a teaspoon of table salt!). However, several studies have shown that, in industrialized communities, the average sodium intakes are as much as 4,500 mg per day (Karppanen & Mervaala, 2006). Therefore, at the opening screens of our system students were presented with some facts that explain the reasons for sodium intake reduction, so they understand it is relevant to them and that they are required to maintain a healthy lifestyle.

Control variables: We recorded gender and age, and also assessed the self-efficacy of the subjects at the beginning of the experiment.

Participants

The sample used for this study consists of 155 subjects. 136 were students recruited in two large public universities and 19 subjects recruited by a forum on the Internet interested in Hypertension. Among participants, 87 were females and 68 were males. The average age was 30.5. Descriptive statistics for the sample are presented in Table 2.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Age</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIP</td>
<td>53</td>
<td>Mean 29.5 (S.D. 11.8) Range 21-72.5 years</td>
<td>Female 62% Male 38%</td>
</tr>
<tr>
<td>VI</td>
<td>52</td>
<td>Mean 31.9 (S.D. 12.6) Range 21-67 years</td>
<td>Female 48% Male 52%</td>
</tr>
<tr>
<td>P</td>
<td>50</td>
<td>Mean 30.1 (S.D. 11.3) Range 21-73 years</td>
<td>Female 58% Male 42%</td>
</tr>
</tbody>
</table>
The people of the Internet forum are not defined as hypertension patients; most of them are healthy people who are interested in blood pressure issues. Following a pilot test we have conducted we found there were no differences between groups so we wanted to check whether this is due to the effect of surprise from exposure to the subject. Our tests showed previous knowledge has no effect on results, and trends of change in subjects' variables were similar in both the healthy group and the Internet forum.

Each participant was randomly related to one of three test groups: VIP, VI, or P. All groups filled in identical questionnaires before and after the task. Subjects were asked to use the system again after two weeks and repeat the exact activities (fill a questionnaire and complete a task that required 30 minutes each time). The information provided about the relationship between sodium and blood pressure was identical, but the interface was different for each group.

The task was to assemble a daily menu from a list of food items currently available in the market. The system would then calculate the total sodium consumption, display it to the users, and show the blood pressure levels they might have had. Other information that was displayed was the maximum daily intake of sodium as recommended by medical staff, and the source of sodium in the food items.

VIP group users had Interactive Visualization of their personal information: the users could retroactively amend their daily menu, in order to reach the recommended sodium level, and accordingly watch the influence of this change on a graph of blood pressure. ("What if" manipulation)

VI group users had the same interface but with general rather than personal information. This group performed all activities on a pre-filled menu containing a sodium intake of approximately 5,000 mg, according to the average in general population

P group users got the full information about their own personal data but in textual and numerical forms rather than graphical (e.g., numbers of blood pressure values) and no interactivity, i.e., they couldn’t change their own daily menu as in the "what if manipulation".

Measures and Instrument Validation

Comprehension was measured using self-developed questions of knowledge about the relationship between sodium consumption and high blood pressure values. The score is a count of the correct answers. The questions were composed with the aid of a nutrition specialist who specializes in DASH (Dietary Approaches to Stop Hypertension). For the Involvement scale, we used measurement instruments taken from O’Brien (2010), from Lee et al. (2010), and from McAuley et al. (1989). The measure of Self-efficacy is based on Bandura (2006). Intention to Change Health Behavior was measured with a self-developed scale based on Ajzen (2006). These measures were calibrated in a series of pilot studies. The items used in this survey are shown in Appendix A. As noted in the appendix, the reliability or internal consistency of each scale was assessed using Cronbach’s alpha values as the reliability estimates and ranged from .85 to .91. A Cronbach’s alpha of .7 is generally considered acceptable (Nunnally, 1978).

Data Analysis and Results

All measures were collected at two points of time: T1, immediately after using the system the first time, and T2, immediately after using the system the second time two weeks later. Self-efficacy was also collected before using the system at both points of time.

We first report on differences between T1 and T2 and then concentrate on T2, which is our target behavior, by examining the hypotheses and reporting a Path Analysis. For each of the four dependent variables we looked at the difference between the score at T1 and T2 and examined whether this difference varied amongst the feedback groups.

Both Self-efficacy and Involvement improved significantly for the interactive feedback groups (i.e., VIP and VI) but not for the non-interactive group (P). The test statistics for self-efficacy and involvement are respectively, $F(2,154) = 5.55$, $p<.01$ and $F(2,154) = 15.11$, $p<.001$. Moreover, we conducted Tukey tests for source of difference for both constructs, which both showed bigger increases for the interactive groups versus the non-interactive. There was no significant improvement for comprehension in any of the groups.
The same analysis for Intentions to change behavior revealed an interesting story. There were no significant differences between VIP group and the other feedback groups but there were at T2.

At T2, Intentions differed significantly between groups $F(2,154) = 4.44, p<.05$. A contrast analysis revealed a significant difference between the VIP group users and users of other interfaces $t(152) = 2.12, p<.05$. The VIP group users reported a higher level of Intention to change health behavior following the system usage. This finding is interesting since there was no increase between T1 and T2 in average Intentions of the VIP group, but there was a decrease of level of Intentions in the two other groups, as shown in Figure 3.

To examine the effect of previous health habits on expectations, involvement and intentions to change behavior we divided the users in two groups - "healthy habits" vs. "unhealthy habits" according to the reported sodium levels prior to using the system. The healthy habits group contains 25% of participants in the sample who reported the lowest levels of sodium, while the unhealthy habits group contains all those who reported high sodium levels 75% percentile.

Then we conducted t-tests for independent samples to examine differences between the groups in the study variables: expectations, involvement and level of intentions to change behavior. Results of the analysis did not indicate a significant difference between groups. This indicates that these groups did not differ significantly in the way they respond to system usage.

**Path Analysis**

Using the IBM SPSS/AMOS 19 package, we performed path analysis to estimate the research model. We chose to use observed rather than latent variables because of the relatively modest sample size (a ratio of 10 respondents per parameter was not obtained) (Hair et al., 1998).

Prior to testing the models, we performed a regression analysis to examine the effect of the control variables on Intentions to change. None of the control variables had a statistically significant relationship with Intentions to change.

The results of our model in Figure 4 indicated statistically significant relationships between: 1) VIP level and Self-efficacy (.282, $p = .002$), 2) VIP level and Involvement (.356, $p < .001$), 3) Self-efficacy and Intention to change (.229, $p < .001$), 4) Involvement and Intention to change (.437, $p < .001$). The findings indicated no statistically significant relationships between VIP level and Comprehension (-.233, $p > .10$) and between Comprehension and Intention to change (-.003, $p > .90$). A chi-square of 8.173 on 3 degree of freedom, and other goodness-of-fit statistics (CFI = .958; TLI = .860) indicate that the model fit the data well.

We also computed an alternative model with a direct link between VIP level and Intention. This path was
not significant (-.015, \( p > .83 \)). All other paths that were significant in our model remained significant. This model showed a good fit with the data. A chi-square of 8.132 with 2 degrees of freedom, and other goodness-of-fit statistics (CFI = .95; TLI = .75) were obtained. This result indicates the mediating role of Comprehension, Self-efficacy and Involvement. When only the direct link between VIP level and Intention to change was specified, the coefficient was statistically significant (.23, \( p = .005 \)) as opposed to the non-significant link noted above when the mediating variables were specified. This is in line with the Kenny et al. (1998) guidelines for establishing mediation. A variable (M) mediates the relationship between an antecedent variable (X) and an outcome variable (Y) if (a) X is significantly related to Y; (b) X is significantly related to M; (c) after X is controlled for, M remains significantly related to Y; and (d) after M is controlled for, the X-Y relationship is zero. Kenny et al. (1998) described these steps as “the essential steps in establishing mediation” (p. 260).

Table 3 demonstrates variable correlations and reliabilities. No reliability is needed for the independent variable (VIP level), and for the comprehension variable which measures the sum of the correct answers.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>S.D.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Rel.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. VIP level</td>
<td>1.98</td>
<td>0.818</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Comprehension</td>
<td>3.33</td>
<td>1.584</td>
<td>.120</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Self-efficacy</td>
<td>3.26</td>
<td>0.933</td>
<td>-.247**</td>
<td>-.052</td>
<td>1.00</td>
<td></td>
<td></td>
<td>.848</td>
</tr>
<tr>
<td>4. Involvement</td>
<td>3.168</td>
<td>0.830</td>
<td>-.350**</td>
<td>.141</td>
<td>-.452**</td>
<td>1.00</td>
<td></td>
<td>.915</td>
</tr>
<tr>
<td>5. Intention to change</td>
<td>2.12</td>
<td>0.841</td>
<td>-.227**</td>
<td>.042</td>
<td>.449**</td>
<td>.545**</td>
<td>1.00</td>
<td>.907</td>
</tr>
</tbody>
</table>

N = 155; Two-tailed test
* \( p < .05 \), ** \( p < .01 \)

### Discussion and Implications

We began this study by asking whether the design of HCI can affect health care behavior, and more specifically, can VIP feedback affect the intentions to change one's diet in compliance with prescribed behavior. We proposed a model in which VIP feedback affects the target behavior through a process characterized by three constructs: comprehension, self-efficacy and involvement. The results support the mediation model, although the comprehension path was not statistically significant. The higher level of intention to change behavior revealed at T2 compared with T1 are especially encouraging because compliance with recommendations after the initial enthusiasm (in our case two weeks) was the trigger for
this work. VIP feedback could provide an opportunity to develop long-term intentions. This is also the case regardless of health habits, as reflected from a comparison we performed between subjects with high-sodium intake vs. subjects with low-sodium intake.

We opted for the holistic approach in design to encompass the gamut of human aspects leading to the target behavior (Faisal et al., 2005) rather than focusing on the target behavior alone (Lockton et al., 2010). This fits nicely with the notion of understanding why elements of the design affect behavior in order to design better systems in the future (Klasnja et al., 2010). Undoubtedly, theory-based designs of HCI will increasingly rely on multiple aspects of physical, cognitive and affective explanations of human behavior. For instance, recent works on systems that support change have relied on models of persuasion (Oinas-Kukkonen, 2010). Behavior is a result of three factors: motivation, ability and triggers (Fogg, 2009). Our work can be seen to complement this approach with VIP feedback as a trigger that is embedded seamlessly into the human computer interaction. It is designed to promote activity and it provides several trigger types. Given the principle of combining visualization, interactivity and personalized-content, we are one step closer to the design goal of delivering the message in a relevant, interesting, informative and persuasive way (Noar et al., 2007).

These results are encouraging because it means that careful design can make a difference. These results become all the more important as the trend toward patient self-management continues to accelerate (Sadan, 1997). Recall the face-to-face dialog at the beginning of this paper. VIP feedback is everything the dialog is not. In the face-to-face meeting with the doctor, the stressed patient sits passively listening to the doctor's monolog and tries to grasp a graph of general trends in the population but cannot relate the message to a target behavior that will influence her health. The patient's only reaction to the doctor had to do with a concrete plan to go to Disneyland the following week. VIP feedback should ensure the patient becomes more involved, understands the impact of the information on her health condition and at the same time feels she is capable of taking the right action of changing her eating habits.

In the context of the move to patient self-management, VIP feedback can be seen as an important mechanism for empowering patients. Moreover, VIP feedback fits well with the change of mind from prescriptions and compliance to a bidirectional communication between doctor and patient that leads to 'adherence to medical treatment' (Osterberg & Blaschke, 2005).

The idea of empowerment of course is not limited to the health arena. It can be found at work, education and environmental action to name a few. In all these situations VIP feedback can serve as a vehicle for change. Moreover, the idea of designing HCI on the basis not only of a target behavior but also on the mediating constructs leading to it can be applied to other aspects of designing HCI.

Limitations and Future Research Directions

Although aiming for a change in actual behavior we stopped short at intentions to behave, relying on their predictive power (Sheppard et al., 1988). We have already begun a similar field experiment with outdoor patients of a major hospital, in which we measure both dietary behavior and Sodium intake. We see the importance of a field study not only in being able to include actual behavior in the study but also to examine the thoughts and behaviors of people for which the problem and outcomes are literally a matter of life and death. It is not at all clear how this intense personal matter affects involvement and comprehension.

In fact, we are concerned about our measure of comprehension. While the measure, a count of correct answers, seems valid, and appeared so in pilot studies, we may need to improve its reliability by developing a new questionnaire. While the measures of intentions, self-efficacy and involvement are easily adaptable to other contexts, the measure of comprehension will have to be tailored to the particular content that needs to be delivered to the user.

Conclusion

The medical world attempts these days to encourage the patients so they can take responsibility over their medical condition, for that purpose the patients need relevant information. There's a gap between explaining medical information to the patients and the way they understand and act according to the
information. The gap is the motivation for this study.

The VIP feedback system we designed has given the users the holistic experience which enabled them to build the internal believes in their ability to change their health behavior.

Our results point to the lasting impact of visual, interactive and Personalized-content feedback, showing how combined feedback provides a more lasting impact than any partial feedback. Our results demonstrate how self-efficacy, comprehension and involvement of users can be effectively manipulated through a simple interactive feedback mechanism.

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# Appendix A. Measurement Items for Principal Constructs

<table>
<thead>
<tr>
<th>Construct</th>
<th>Items</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-efficacy</strong></td>
<td>I’m certain I can control the level of my Blood Pressure</td>
<td>Self developed</td>
</tr>
<tr>
<td></td>
<td>I’m certain I can maintain a low sodium diet for a long time</td>
<td>based on Bandura (2006)</td>
</tr>
<tr>
<td></td>
<td>I’m certain I can find low sodium substitutes for every food I like</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I feel I can plan on my own a daily low sodium menu</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I know what to avoid eating in order to prevent high blood pressure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I need the assistance of a dietician or a doctor to plan a slow sodium daily menu</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I feel I control the amount of sodium in my daily menu</td>
<td></td>
</tr>
<tr>
<td><strong>Comprehension</strong></td>
<td>I estimate that the main source of sodium in my food is from salt I add to my plate during the meal</td>
<td>Self developed Right/wrong questions. Count right answers.</td>
</tr>
<tr>
<td></td>
<td>In order to reduce salt consumption, The most important action is:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• stop adding salt during cooking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• stop adding salt to my plate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• eat less processed food</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I estimate the amount of my daily sodium intake is...</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I estimate that the percentage of sodium from my daily sodium intake derived from processed food is</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Which of the following food items contains a higher amount of sodium?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A decrease of one mmHg of systolic blood pressure can be achieved by reducing the daily consumption of:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 300-1000 mg sodium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 1500-2000 mg sodium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 3000 mg sodium</td>
<td></td>
</tr>
<tr>
<td><strong>Intention to Change Health Behavior</strong></td>
<td>I made an exact plan how to transform my menu to a low sodium menu</td>
<td>Self developed based on Ajzen (2006)</td>
</tr>
<tr>
<td></td>
<td>I made an exact plan when to change my nutrition habits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I made an exact plan in which situations I should avoid eating sodium enriched food</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I intend to eat a planned daily menu during the following week</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I intend to plan a low sodium menu during the following week</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I intend to check the amount of sodium on food labels during the following week</td>
<td></td>
</tr>
</tbody>
</table>
I'll refrain from using salt during cooking during the following week
I'll reduce processed food consumption during the following week

<table>
<thead>
<tr>
<th>Involvement (sample of the 16 items)</th>
<th>I was really drawn into my nutrition management task.</th>
<th>Self developed based on O’Brien (2010); Lee et al. (2010); McAuley et al. (1989); Cronbach’s Alpha = .915</th>
</tr>
</thead>
<tbody>
<tr>
<td>I felt involved in this nutrition management task.</td>
<td>This learning experience was fun</td>
<td></td>
</tr>
<tr>
<td>This type of computer program allows me to be more responsive and active in the learning process</td>
<td>This type of computer program allows me to have more control over my own learning</td>
<td></td>
</tr>
<tr>
<td>This type of computer program allows me to have more control over my own learning</td>
<td>This type of computer program promotes self-paced learning</td>
<td></td>
</tr>
<tr>
<td>This type of computer program helps to get myself engaged in the learning activity</td>
<td>This type of computer program helps to get myself engaged in the learning activity</td>
<td></td>
</tr>
<tr>
<td>I would describe this type of computer program as very interesting</td>
<td>After trying this type of computer program for a while, I felt pretty competent to manage my nutrition.</td>
<td></td>
</tr>
<tr>
<td>This type of computer program did not hold my attention</td>
<td>It was important for me to do well at the task of understanding how to reduce the amount of daily sodium intake to 2,300 mg.</td>
<td></td>
</tr>
<tr>
<td>I was satisfied with my performance in the task of understanding how to reduce the amount of daily sodium intake to 2,300 mg.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>