Factors that Help and Hinder a Daily Weighing and Reporting Behavior

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CHI'17 Extended Abstracts, May 6-11, 2017, Denver, Colorado, USA.
ACM 978-1-4503-4656-6/17/05.
http://dx.doi.org/10.1145/3027063.3053206

Abstract
People living with chronic health conditions have two common challenges: implementing positive health behavior habits, and monitoring & reporting their health status regularly. We examined how the use of a mobile app can help patients face these challenges in the context of a scenario in which a patient needs to weigh themselves daily and report the data to their care team. We implemented a habit formation technique to help people establish the daily weighing habit and tested the use of a WiFi-connected "smart" scale to help people with data reporting. We found that the smart weight scale did improve compliance compared to a manual scale, but that the habit manipulation ("implementation intention" plus coaching through text messaging) did not have an effect. Emergent factors, identified through coding of interviews, raised additional hypotheses about mechanisms involved in determining compliance with a daily weighing habit.

Author Keywords
Daily weighing habit; compliance; smart scales; implementation intention; coaching.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

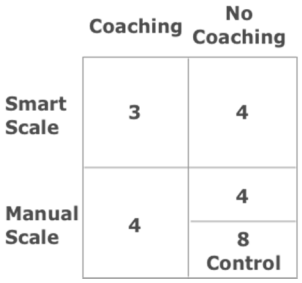

Figure 1. Study design. N=23 participants (15 across experimental conditions, 8 controls).

Introduction

There is a growing acceptance in both the clinical and health research communities that individuals with chronic disease(s) can benefit from the use of mobile, wearable, and other technology tools to self-manage their conditions [10]. Research also shows that multi-component interventions are needed to significantly impact long-term chronic health problems [1,3,7]. However, much remains to be learned about how to effectively deliver technology solutions alongside medical care delivery for better care.

People often need to develop new habits to manage their chronic conditions, but ongoing compliance with these habits is a never-ending challenge. In this study, our group, which is involved in building tools to support patients with chronic diseases, focused on the habit of reporting daily weight. Daily weighing is often requested of congestive heart failure (CHF) patients or those on diuretics. The cornerstone of CHF self-management requires an individual to both measure and report her daily weight to a designated party (e.g., primary care team) [2]. However, the daily weighing behavior could be generalized to other repetitive behaviors such as blood pressure recording or symptom reporting.

Our research explored two paths. With support of a mobile application, the first focused on establishing the daily weighing habit in healthy volunteers and the second focused on eliminating obstacles to reporting the results.

Establishing a Habit

The construct of *habits* is often mentioned for its role in helping individuals make long-lasting changes in health behaviors [9]. A habit is defined as an automatic response to an environmental cue that is built up through repetition of the behavior; once established, a habit requires limited involvement of conscious thought [6]. Lally et al [6] found half of their participants reached asymptotic habit strength within 34 days for simple behaviors such as drinking a glass of water, cued by lunch.

We explored habit formation through environmental cues. A key approach was to attempt to insert a new cue around pre-existing cues. Gollwitzer [5] calls this an "implementation intention" and demonstrates better goal attainment when individuals formulate plans such as *"whenever situation x arises, I will initiate the goal-directed response y"*, especially for target behaviors deemed "difficult" [5]. In our study, some of the participants were coached to identify a *cue*, for example a well-established morning behavior such as brushing one's teeth and attach to it the intention to weigh oneself. Using follow through we attempted to help participants recognize the success of the accomplishment of a successful design. Lastly, these participants received supportive messages and help through the app from a "coach" over the course of the study.

Data Reporting Behavior

External events, unrelated to motivation may prevent successful *completion* of the patient's task. For example, unexpected travel or a changed schedule have been identified as preventing follow through for an intended behavior [3,7]. While one might have the habit of stepping on a scale on a regular basis, we explored this issue by varying the type of scale available to our study participants; either a "smart

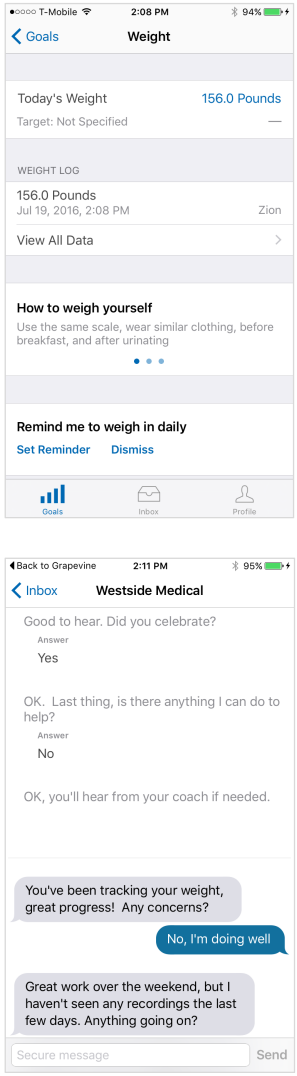

Figure 2. Screenshots of our mobile app. Our app was developed for iOS.

scale" that transmits the data via WiFi or a manual scale requiring manual transmission of results.

Method for Daily Weighing Study

Participants. We recruited twenty-four employees in our organization, a global technology company. Participants were recruited without regard to health condition, communicated an interest in weighing themselves regularly, and stated that they had no prior daily weighing habit. One participant with a family emergency dropped out after the study had begun, leaving 23 participants in our final sample.

Study Protocol. Participants were required to weigh themselves daily for 30 days and report the data through a mobile application (n=15) or record the time on a paper form (n=8). In an on-boarding interview, participants signed an informed consent form and were instructed to *"weigh yourself daily at the same time, after urinating and before eating or drinking, wearing the same amount of clothing, and using the same scale placed on a hard, level surface"*. These are the standard medical instructions given to patients who must weigh themselves for medical reasons [2]. At the end of 30 days, an off-boarding interview was conducted with each participant.

Study Design. Of the initial 24 participants, eight served in the *control group* and the remaining 16 were divided into four groups created by crossing the factors of Coaching (yes, no) and Scale Type (manual, "smart"). Figure 1 shows the distribution of participants across conditions.

Mobile App. During the on-boarding, everyone but the *control group* was set up with a mobile app (iOS) that our team designed to record their weight. Our app's key features were the collection of weight data from a smart scale (via Apple's HealthKit) or manual entry, messaging with the coach, and a reminder option. Screenshots of our app are shown in Figure 2.

Smart Scale vs. Manual Scale. In the case of the two *smart scale* groups, participants were set up with a Withings WiFi connected scale [12] which captured their weight data in its companion app and reported it to HealthKit; our app then received the weight data via HealthKit. The manual scale groups recorded their weight in our mobile app directly.

Coaching. With help from one of the experimenters (the "coach") during the on-boarding session, participants in the *coaching* conditions identified an established morning habit to act as a *cue* for daily weighing. Throughout the study, they received encouraging messages from the "coach" via the mobile app (daily for the first week, every other day for the next eight days, and then "as needed" based on the participant's compliance).

Data Collection and Regression Analysis. Both qualitative and quantitative data were collected. Quantitative data consisted of the dates and timestamps of weight recordings. Qualitative data were derived from the on- and off-boarding interviews, which were transcribed and coded by three experimenters. Responses to some interview questions were transformed into binary factors (e.g., reporting the use of a visual cue used as reminder was coded as yes/no) for inclusion in a regression analysis to predict compliance rate. This enabled us to identify potential *emergent factors* involved in the study behaviors. A

correlation matrix was computed for these emergent factors along and the experimental factors (type of scale, coaching) and one in each pair of highly collinear factors ($r > .50$) was eliminated. The regression analysis included the experimental factors of scale type scale, coaching, and emergent factors for the presence of general or specific weight goals, the experience of various kinds of disruptions in the weighing habit, and the use of external cues to maintain habit adherence (physical or digital reminders).

Results of Consistent Daily Weighing

Adjustment for days without access to scale. A common compliance barrier was being away from home, without access to a weight scale (usually due to travel). Considering these events were outside of a person's control (many of our employees must travel as part of their job), we adjusted the study duration downward by the number of days participants reported traveling; we call this the effective study duration. Compliance rate was calculated by dividing the number of days with reported weight data by the effective study duration. This overall *base compliance rate* was 82%.

Variation in reporting time. Due to the fluctuations in human body weight over the course of a day [8], it is important to be consistent in the timing of weighing oneself daily. This led us to only count reporting times within a two-hour range centered on their median reporting time. For example, if a participant's median weight time was 7:30 AM, we only counted weight times between 6:30 AM and 8:30 AM. After applying this rule, the *adjusted compliance rate* was 56% across all participants. We use the adjusted compliance rate in the rest of the paper.

Discussion. When we applied the two-hour window rule to compliance rate, the resultant figure dropped from 82% to 56%. Of the 15 participants in the experimental groups, only one had a compliance rate of 100%. Three had a compliance rate of at least 75%, 8 had a rate of at least 50%, 12 had a rate of at least 25%, and the remaining three ranged from 7% to 23%.

Participants reported that consistent timing was difficult especially on the weekends when they woke up later than during the work week. Sometimes they also forgot on weekday mornings, but remembered later in the day. Given the clinical importance of adhering to a time-based schedule, medical professionals should emphasize the importance of timing to patients. This problem may be less common among patients with advanced chronic conditions than for our sample of healthy volunteers if they have more routinized daily experiences. Alternatively, analytics-driven weight monitoring might be able to remove the time requirement [4].

Elimination of control condition. The *control condition* is not considered in further analysis for two reasons. First, as members of the control condition recorded their date and time of weighing in 2-hour time periods (i.e., 6 - 7:59am) through a paper form, we were unable to calculate their *adjusted compliance rate*. Second, some of these participants reported in the off-boarding interview that they recorded data in batches (also reported in [6]) rather than at task completion; thus, accuracy of these results is questionable due to memory effects. In the future, recording data in the control condition could be improved via digital means, such as by text message or email.

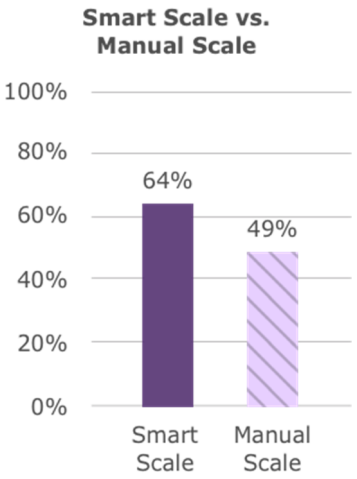

Figure 3. Mean compliance rate for study participants using smart scale and those using a manual scale.

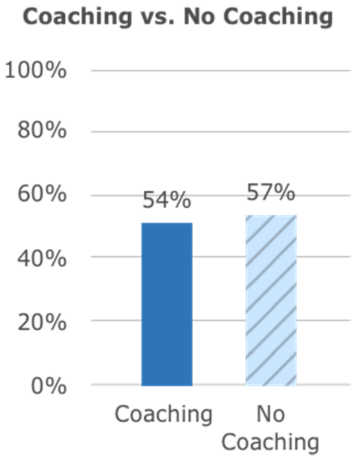

Figure 4. Mean compliance rate for study participants in the coaching conditions and those without coaching

Effect of Smart Scale vs. Manual Scale

As can be seen in Figure 3, the use of a smart scale had a positive impact on compliance with the daily weight request relative to the use of the manual scale (64% compliance vs. 49%; ß=.57, t=3.09, p=.04). The main benefit of the WiFi-connected scale is that it eliminates the step of manually recording weight data. In the off-boarding interviews, 3 out of 8 manual scale participants reported encountering this challenge. Although the smart scale eliminates these obstacles, it came with its own set of challenges. It had burdensome set up, maintenance, and troubleshooting processes even with our technologically-savvy participants. Six of the seven users of the smart scale reported problems.

Discussion. Our results suggest that the type of device – smart or manual – to be used depends on the circumstances of the deployment. As has been reported by others [2], smart devices often require dedicated support staff for valid data collection. Alternatively, additional training might be effective for increasing the reporting rate when using a manual scale.

Effect of Coaching

Cue Selection and Supportive Messaging. As can be seen in Figure 4, there was no effect of the coaching factor on compliance with reporting a daily weight (54% with coaching vs. 57% without; ß=.04, t=0.29, p=n.s.).

Perhaps our implementation cues and cue design had an impact. Six of the seven participants in the coaching conditions reported successfully implementing the cue they had selected in discussion with the coach. However, they complied less rigorously with the directive to recognize success when they accomplished their daily goal. Four of the seven reported no recognition and the three others reported occasional recognition.

We also examined the nature of the messaging between the coach and the participants, which was intended to ameliorate any problems the participant might encounter with daily weighing and to communicate additional encouragement. Although the coach did adhere closely to the messaging protocol we designed and initiated most messaging exchanges, study participants replied to only approximately 35% of the coach's messages. This rate increased to 51.5% when the coach's message was a question, but was 16.8% when the message was in statement form (e.g., an encouraging message).

Discussion. Unexpectedly, we failed to observe a positive effect of coaching on compliance with daily weighing. It is not possible to rule out either of two theoretically-specified possibilities: 1) failure of the participants to recognize their accomplishments [4] and 2) the use of a too-simple task [5]. Our data raises a third intriguing possibility, that failure of participants to sufficiently engage in messaging interactions with the coach may have rendered the coaching manipulation ineffective. Our data suggests that direct questions from the coach may be a way to engage participants in a dialogue and obtain benefit for habit formation.

Emergent Factors

Impact of Pre-existing Weight Goals. In the on-boarding interview, we queried study participants as to any weight goals they might have. We coded responses as none, general (e.g., *"I'd like to lose some weight"*) or specific (e.g. "*I'm going to try to lose 5 pounds in*

the next month"). Having a specific weight goal had a positive effect on compliance with daily weighing (*ß*=.65, *t*=3.27, *p*=.03).

Impact of Disruption. In addition to adjusting the outcome measurement for travel during the study period, participants reported other obstacles such as *hosting visitors at home, family weekend plans,* and *acute work demands*. We grouped these into a factor we called "one or more disruptions." This factor marginally lowered compliance with daily weighing (*ß*=-.43, *t*=-2.39, *p*=.08). This finding is consistent with the work of others [6].

Effect of External Cues. Six of the 15 study participants reported they used a visual cue to help them remember to weigh themselves. Typically, this was seeing the scale, usually placed in the bathroom, during one's morning hygiene routine. The regression analysis indicates that this factor had a *negative* effect on compliance (*ß*=-.38, *t*=-2.74, *p*=.05). Some other participants reported using digital external cues, such as reminders in the app or on their mobile phones. The regression analysis indicates that this factor had a marginally negative effect on compliance (*ß*=-.39, *t*=-2.45, *p*=.08).

Discussion of Emergent Factors. The coding of the interview data enabled us to statistically assess some of the observations participants made in the interviews. Two of these – the positive effect of specific weight loss goals on compliance and the negative effect of disruptions – make intuitive sense. Having a pre-existing reason to weigh oneself improved compliance; thus, we would expect patients who have been instructed on the importance of daily weighing to be more compliant overall than our healthy volunteers. The effects of external cues lessening compliance requires further investigation. There is precedence for this result in the work of Stawarz et al [11] who argued that using external reminders lessens the need for habit formation, by shifting intrinsic motivation to extrinsic. Also, a finer grained analysis of our data showed that at least some of the participants noted that the cues were not reliable, such as when the digital reminder triggered after they had left the house, or another person in the household moved the scale and thus eliminating the visual cue. A caveat to consider is whether the precision of the qualitative data was sufficient to correctly assess these factors.

Conclusions, Limitations, and Future Work

Our pilot study helped us to identify future directions to explore in the design of technology to support individuals who must perform simple self-care tasks regularly. Identifying emergent factors in interview data were tested with regression techniques and highlighted the role that external factors may play as potentially *negative* influences in adherence. More rigorous data collection to improve both the precision and expand the richness of the data is needed to help explore mechanisms whereby these factors may exert influence. In spite of negative results in the coaching conditions, we believe our data points to some worthwhile directions to pursue. We are particularly interested in exploring interactive messaging for its potential in furthering habit formation. Embedding this in an automatic system could help with scaling a currently resource-intensive method. Finally, limiting future studies to individuals with pre-existing reasons for daily weighing will help improve the ecological validity of empirical work with analogue populations.

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