# Investigating behavior change indicators and cognitive measures in persuasive health games

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## ABSTRACT

Most outcome-driven studies designed to evaluate health games or Apps either target usability factors, or are merely measure health-based outcomes in the short-term. Invariably, thus, evaluative studies remain limited in revealing factors affecting long-term behavior change. In this paper, we tackle this issue through adopting a comprehensive approach to investigate the effect of a health game in a 3-month longitudinal study. Using generalized multilevel linear models of outcome changes in BMI, engagement with the game and participants' cognitive precursors after playing the game we found that in-game factors (e.g. certain social activities) were strong predictors for a forward momentum in participants' motivation to change behavior related to physical activity and nutrition. We also found regularity in gameplay to be strong a predictor for BMI changes. This paper contributes (a) these results to further advance the design of games for health and health apps, and (b) presents an evaluation method to advance empirical approaches for assessing health benefits from using games and health apps.

## Author Keywords

Health-based games, games for health, persuasive games, adherence, body mass index, readiness to change

## General Terms

Experimentation, Human Factors.

## Keywords

Cognitive precursors.

## 1. INTRODUCTION

In the past decade or so, the use of pervasive and persuasive mobile Apps and games that promote healthy behaviors has been on a constant rise. Pew reports that as of 2012 at least 72 % of cell phone users went online seeking health information about diseases or certain conditions, treatments or procedures; and that 7 out of 10 people in the U.S have tracked a health indicator for themselves through mobile or online apps [14]. The ubiquity of access to and use of health and wellness Apps has re-energized research in the fields of HCI, usability and health technologies. The potential in health games and Apps to bring about sustained health behavior change has prompted many in the field of health and games to look for dependable metrics and reliable study approaches to combat obesity and associated chronic ailments, especially since these challenges have persisted for over two decades [13,43]. This growing research interest in the field of health games and Apps has yielded several studies keenly focused on evaluating, and sometimes even critically questioning [28,29], the efficacy of health games or "gamified" apps in bringing about sustained health behavior change [12].

However, often outcome-oriented studies are limited to evaluating factors that impact behavioral outcomes in the long-term. Studies designed to evaluate health games or Apps tend to look for changes in the short-term, often within one or two play sessions during which usability factors, such as influence of avatar designs on body image and perceptions on self-efficacy [37,44] or pre- and post-gains in intensity of physical activity within a play session [26,46], are measured. Furthermore, often such studies are conducted in lab-settings so as to maintain consistency with experimental conditions and control them. Recently, exclusively clinical methods like these have come under serious critique by researchers in the field of HCI who point out that studying behavior change in a clinical setting may not be effective in evaluating the effectiveness of such technologies, most of which are built with the premise of being "accessible-anywhere", and therefore inherently ubiquitous [16,24].

Recent arguments stemming from the field of game user research advocates the benefit of focusing on specific strategies and processes that are more effective in bringing about change in behavior through evaluation of technology interventions within naturalistic settings. For instance, Consolvo, et al. [7] argue that when evaluating technologies using well-established theoretical constructs for explaining human behavior, such as goal-setting theory [27] or the Transtheoretical Model (TTM) for health-behavior change [40] it is more beneficial to study processes that cause or promote behavior change. These processes ought to include strategies that gradually foster behaviors that work well with certain lifestyle. As an example of an effective behavior change strategy, they argue that health Apps can be made more pervasive when they are designed to "encroach upon" individuals' personal as well as their social spaces [7]. Similarly, some studies have proposed that *acceptance models* and *personality* traits be accounted for in the design of persuasive health technologies in order to achieve higher success with the interventions [4,18]. Few empirical work in design of persuasive technology report that personalized designs are effective when targeting individuals' personality types [3]. In other words, Arteaga, et al. [3] report that


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when design features were better suited to individual's personality they were more likely to be adopted and adhered to. As argued by these studies, we find that invariably, many evaluative studies remain inconclusive or are unable to establish factors that are effective in the long-term behavior change. They are either too narrowly focused on usability issues or limited to short-term health outcomes. As argued by Consolvo et al. [ref] it is important that contemporary research in health technologies ought to consider not only health-based outcomes, such as adherence to physical activity, gain or loss of weight, but also look for shifts in cognitive precursors to specific behavioral measures, such as self-efficacy, change in attitudes, perception, motivation states and knowledge and awareness about nutrition or physical activity [1,23]. In fact, some very recent work in behavior change are starting to find efficacy in self-affirmation techniques that could promote exercising [20] and that interventions succeed in the long run when they establish a relationship between behaviors, environment and cognitive/affective processes [35].

In this paper, we investigate the evaluation of long-term behavior change of a health application through a comprehensive approach that includes investigating both the effect of a health game on health outcomes and the change in participants' cognitive precursors, or attitudes and perceptions towards their health. We study this phenomenon within the context of a health game called *SpaPlay* developed to promote healthy eating and physical exercise. In particular, we investigate the impact of longitudinal gameplay on behavior change through investigating the effects of gameplay on behaviors in real life while observing both shifts in players' attitudes and behavioral outcomes. We present results from a 3-month long game-play study that we conducted with 47 participants in which participants were asked to play the game and respond to monthly questionnaires assessing participants' weight loss or gain, motivation stage for health behavior change and nutritional knowledge. Findings from the study indicated that there are clear shifts in players' perceptions about health and nutrition knowledge. This study contributes to the field of health behavior change interventions by extending our current understandings on how we might measure longitudinal outcomes in health behaviors through the use of persuasive technologies and, presents recommendations for the design of health interventions that may have longitudinal impact. The contributions from this study are bi-fold. First, we present evidence that indicates how factors external to the game, such as *cognitive precursors* help refine design or features in the game that can better predict engagement and adherence to the game. This is a contribution to advance research in design or persuasive technologies for health. Second, from a methodological standpoint we present an evaluation approach that is better suited to assess efficacy of persuasive health technologies, particularly when the goals are to effect behaviors in the long-term.

The paper is organized as follows. We first provide an overview of the prominent work in the area of health behavior change and games or ubiquitous technology as health interventions. We then describe *Spa Play*, the health game we investigated. We also discuss the study design that incorporated data from both gameplay and player responses external to the game as well as the results of the study. In our discussion of results we focus on the connections between health outcomes, cognitive/behavioral measures and gameplay. Finally we conclude with limitations in our study and some implications for future work.

# 2. PREVIOUS WORK

## 2.1 Exergames and measuring behavioral outcomes

For the most part, the range of games designed to promote healthy behaviors include exergames, or games that incorporate motion-sensing devices that help to track movement and thereby motivate players to exert themselves physically. In these games, users usually see a simulated virtual representation of themselves (Avatar) or part of themselves (tracked limbs) while they are asked to perform a task by moving their body. Such games are designed to be physically intuitive and suitable for users who have no prior gaming experience. Popular examples include the *Nintendo Wii Fit*, which facilitates diet and exercise tracking on a game console, *Wii Sports*, which incorporates physical movement in gameplay, *Zumba* game on Kinect, which incorporates dance to motivate exercise and *My Weight Loss Coach* and the *DS game Pokémon HeartGold*, which use activity-tracking monitors, like pedometers, to promote real-life physical activities. Overall, in exergames the design premise is to use avatar representation and visual display of ongoing real-time activity on the screen to engage players in physical activity for a long play session. Evaluation in these studies mostly focuses on immediate player responses to the game and measures physical exertion in a one-time game play session [19,44] or measures gains in activity levels through a pre-and-post gameplay session evaluation [34,46]. There are several evaluative studies (we will limit the examples to a few to illustrate the basic approach here) that are conducted as short play sessions and measured the experience within those sessions. These studies mostly focus on evaluating the efficacy of the hardware or the software product itself and largely by-pass individual motivational aspects that affect behavior change. This is problematic when we want to narrow down factors that can reliably predict sustained engagement that are especially, since long-term sustenance of motivation is critical in managing health conditions, like as weight-gain or obesity [49]. This has been a well-studied issue that has been tackled by several prominent researchers in the health and technology domains. In the next section, we present a few examples from studies that have sought to tackle behavior change indicators using a more integrated behavior model in addition to measuring immediate psychological outcomes.

## 2.2 Cognitive-Behavioral approaches to measure behavioral outcomes

More recently, studies of persuasive games and ubiquitous health technologies have started to investigate health behavior change in game-like environments that transcend "console-play". These types of simulated environments or games incorporate design techniques that strategically provide relevant information about health, such as how to manage certain health conditions or nutritional choices. As a design strategy, such game environments use compelling story-lines within the game to generate awareness about certain ailments and immerse the players in challenging decision making scenarios [2,5,21]. Furthermore, there has been some interventions that blur the boundaries between virtual and real-world through engaging players in activities that permeate both the game-world and the real world (e.g. "*Zobmies Run*!" in [45]). These games are primarily geared towards fostering certain health dispositions in players and leveraging their intrinsic motivation to attain a healthy lifestyle, so that they are better trained to manage their own health [17,21]. Studies have found that individuals tended to engage with health technologies more regularity when using non-traditional means (e.g. mobile Apps versus pedometers) and, sometimes just by using different ways to monitor their activity through devices, like mobile activity trackers [3,17,22,25]. Other strategies that have been successful are ones that provide small goals with progressive rewards [23, 33]. However, studies have also found that while such persuasive design factors in the game or App seemed to encourage certain behaviors the findings remained inconclusive on associations between device use and health behavior change effects [15]. This type of disconnect is, unfortunately, not uncommon, and present examples illustrating the challenge of designing outcome-based studies in health. Hence, we draw upon literature in the field of health sciences to present our approach to study design combining both technology-based data and participants' *cognitive precursors*.

Within health sciences, for several years now, research on longitudinal behavior change has successfully demonstrated and empirically verified the efficacy of several integrated behavior models that take into account both action and process when evaluating success of health interventions. Some of these include frameworks such as the Transtheoretical model (TTM) of behavior change [40], precaution adoption process model [48], planned reasoned action, and planned behavior models [32]. Prochaska and Clemente have argued that behavioral processes alone may not be useful for predicting long-term change and at times, effective interventions are the ones that allow for "cognitive re-structuring in the individual's sense of self-efficacy" (p-277, [38]). Prochaska and Velicer's extensive review of health interventions based on the transtheoretical model is a great example of how integrated outlook on behavior change influences effectiveness of interventions, and therefore necessitates both behavioral and cognitive measures. In it, the authors state that when interventions are personalized, or "stage-matched" they are able to produce remarkable impacts on a majority of at-risk populations [40]. We, therefore, in our data collection process incorporate motivation state change on of the *cognitive precursor*, in addition to assessing participants' weight-loss or measure the extent of gameplay. In the following sections we describe these in further detail through the context of the study, rationale for using specific evaluative cognitive measures targeting movement in cognitive precursors (e.g. motivation stage) while corroborating it to health-based outcomes (e.g. weight loss).

# 3. STUDY CONTEXT: A HEALTH AND WEIGHT-LOSS GAME

The context of this study is a gamified virtual environment, *SpaPlay* designed to promote healthy eating and exercise for individuals, particularly women, wanting to lose weight or simply start adopting a healthier lifestyle. In this paper, we explore the longitudinal impact of playing this online social game. The data corpus analyzed and presented in this paper is drawn from an ongoing, longitudinal initiative to study the potential of persuasive gaming technologies to promote sustained health behavior change. Through an ongoing design and research collaboration with a commercial game company IgnitePlay, we embedded several design strategies within the health game to incentivize real-life behavior change [10,11]. In this study we are interested in the effect of the game on health behaviors.

## 3.1 Description of the Game — *SpaPlay*

The game, titled *SpaPlay* (see figure 1) is a health spa island, in which a player starts with a few buildings or resources, an avatar, and some virtual currency. The central design intent of the game is to bring playfulness to physical activities that the players can incorporate in their daily routine and be rewarded for their efforts to be physically active and eating healthy in their lives outside of the game. *SpaPlay*, like many other social media environments, operates under an economy model, which encourages the collection of virtual currency to allow players to purchase tangible and intangible rewards. Tangible rewards may be coupons, or invitations to exclusive deals from partner companies. Intangible or virtual rewards are power-ups within the mini-games in *SpaPlay*, or achievement points in the social media environment that allow players to unlock specific decors to decorate and personalize their environments, or virtual assets for their avatars. Players can also invite friends and build their social network. The game provides several ways for players to incrementally increase exercising and start eating healthier through managing their virtual island. Players earn experience points by doing activities that are referred to as *sparks* in the game, which are small activities that players can fit in their everyday routine, like "eat a fruit for snack". Players can also earn experience points by doing planned longer activities, or quests, which are goal-oriented and typically take about a week to be completed, such as "beginner training for biking" that is a quest in which the player has to get the bike in shape to be ridden, mark up a route and bike at least 3 times in that week. Apart from *sparks* or quests that are based on real-world activities, the game also has activities in-game to manage their virtual island-activities, such as picking up trash, planting trees or changing the layout of the island by moving the buildings and other structures around.

The game was designed based on the PENS (Player Experience of Need Satisfaction) model [9,41] through incorporating specific gamification techniques that engage participants in a virtual game world with rewards and incentives for healthy behaviors they do outside the game world. *SpaPlay* interweaves health concepts within the structure of a social virtual world. Drawing upon the three levers of intrinsic motivation as postulated by the theory of self-determination [9] autonomy, competence and relatedness, the game mechanics in *SpaPlay* are structured in ways that optimally satisfy player autonomy and give players ways to grow their abilities and gain mastery of through progressively challenging quests that are personally meaningful for meeting their health goals.


**Figure 1. Tracking of Meals and Calorie Intake. The screenshot also shows, in the upper left, the avatar of the character with virtual currency, levels accomplished, etc.**

For instance, in order to empower players with autonomy and provide them ways to manage their competence, *SpaPlay* provides players with various ways to monitor their physical and dietary activities (see Figure 1). Some of the ways players can monitor their activities is through visualizing how much they exercised in a day, week or month (see Figure 2) or compare their own activities with the friends in their in-game network (see Figure 3).

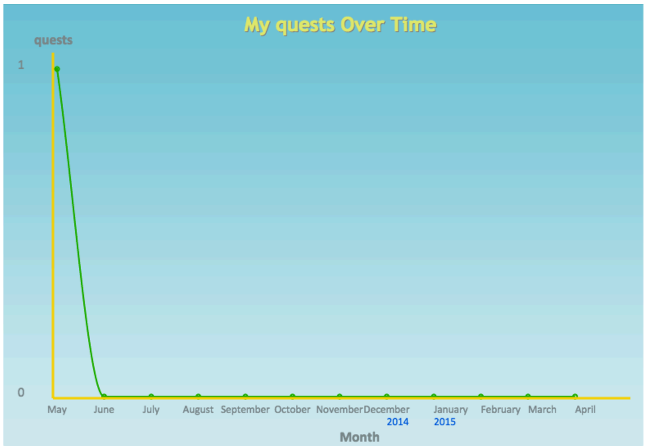


**Figure 2. Chart showing quests over time**


**Figure 3. Visualizing progress in comparison with friends**

Players can log their eating and food choices through the game and also connect their physical activity sensors, such as pedometers (e.g. Fitbit) or external running Apps on phone (e.g. RunKeeper). Data from these systems are integrated into the game and users can view this data through the game and get rewards based on this data. *SpaPlay* also uses the data for motivational purposes:

- *Visual feedback and rewards for physical healthy actions:* Character level and appearance are tied to data collection and physical activity. Thus, rewarding such behaviors is reflected through new content rendered in the game.
- *Social Dimension to Sharing of Healthy Activities.* Due to its social nature, *SpaPlay* allows players the choice of sharing some information with their friends. This adds an important motivational factor on the relatedness scale from Rigby and Ryan [41]. This is currently implemented in *SpaPlay* in various ways to tie into several motivational concepts discussed in the PENS model. One example of motivating a player is through providing a visualization of progress of a challenge activity, thus appealing to players who are motivated by the element of competition.

*SpaPlay* also includes several systems for raising awareness to health-based concepts. For example, it includes visualizations of different food types compared to the level of exercise needed. Another example is the use of games that have health-based themes, such as the Yoga game, which embeds understanding of Yoga poses through a bejeweled style game, and the Chef game, wherein users play a diner dash-type game to put together a healthy dish based on healthy recipes, either encoded in the system or supplied by friends of the user through the social media.

It is important to note that while the specifics of the implementation, theme and visualizations differentiate *SpaPlay* from other health based behavior change games, *SpaPlay* shares many techniques and reward systems with other health-based apps that target increasing physical activity and healthier nutrition choices, like *MyFitnessPal*, or *NutritionHub*. Thus, while our study data is from a particular game, we are not presenting *SpaPlay* as a unique game. We present the game as an instantiation of a genre that includes several such gamification techniques and thus, suitable for investigating the relationship between its design and various important health measures, such as engagement, adherence, and behavior change.

## 3.2 Study Design And Data Collection

As argued earlier, health behavior change depends not only on observed behavioral outcomes, but also depends upon several precursors, such as self-efficacy [31], nutrition knowledge [36] and barrier to exercise [6,47]. Accordingly, we collected behavioral data from logs of play actions in the game and tracked changes in measures related to precursors, such as readiness to change and baseline measures, on participants' current physical activity levels, eating preferences and basic overview of their gaming preferences (e.g. console games versus, Cellphone or Facebook Social games).

### 3.2.1 Screening and Participant Recruitment

For this study we used several screening measures to select participants. In addition to selecting only female participants, since the game is designed for a predominantly female audience [11], we filtered participants based on their motivational stage of change. Stages of change is an useful framework for studying behavior change, which has been extensively used for designing and tailoring interventions to help individuals manage chronic health management or combat substance abuse. The model posits that in terms of motivation, individuals may be grouped under different stages of readiness for change (pre-contemplation, contemplation, preparation, action or maintenance) and given a baseline stage, the model can be used to predict behavior change [8,30]. The foundational work on readiness for change, or also known as the transtheoretical model (TTM), defines these stages as follows: 1) pre-contemplation: no intention to take action within the next 6 months, 2) contemplation: intends to take action within the next 6 months, 3) preparation: intends to take action within the next 30 days and has taken some behavioral steps in this direction, 4) action: changed overt behavior for less than 6 months, and 5) maintenance: changed overt behavior for more than 6 months [39]. The rationale behind detecting the motivational grouping of individuals is that one might design interventions that would promote certain decisions that are more likely to empower individuals to move through to the next stage in making positive change in behavior.

We collected participants' predispositions towards health and their intrinsic motivation using the Readiness to Change Questionnaire and recruited individuals in the contemplation or preparation stages, we sought to detect shifts in their perceptions during the 3 months they played the game..

### *3.2.2* Data Collection

In addition, we also collected gains in knowledge about nutrition and healthy eating and body weight differences over the period of 3 months, administering the questionnaires once every month [36,50]. We asked participants to fill in the questionnaires and BMI measures at baseline and once every month, resulting in four data points during the 3-month study.

The data corpus of the study is as follows:

1. Behavioral logs automatically collected and time stamped for every player action in the game. These records captured all participants' engagement with the game within a day across the 3 months of the study. It should be noted that behavioral logs here are only player actions in-game and do not show or uncover motivational or cognitive elements for why people exhibited such behaviors.
2. Responses to a 94-item questionnaire composed of: the TTM/stages of change constructs, nutritional knowledge and baseline body weight measures. The instruments were administered at baseline (beginning of the study) and every 4 weeks in the study for the period of 3 months.

In addition, information pertinent to participant demographics was also collected during the first screening that included age, highest education level attained, ethnicity, weight and height.

# 4. RESULTS

## 4.1 Summative Overview of Participant Breakdown based on Baseline Measures

Of the 60 female participants initially recruited, who were screened to be in the pre-contemplation or contemplation change based on their responses to the readiness to change questionnaire (explained in further detail in previous section), 13 dropped out within the first week of the study. Primary reasons that participants attributed to dropping out included —

1. Lack of gaming experience or unfamiliarity with gaming (these were women over 50) and reported lack of interest in games.
2. Lack of commitment and inability to provide adequate time to the study — again, these were also individuals who were in pre-contemplation stage. It is to be noted that while the stages are clear constructs to detect individuals' motivational levels, as Prochaska, Redding & Evers caution, definitions of stages are not mutually exclusive, especially when "health behaviors are complex" and this means individuals in lower stages would need to perceive a greater number of benefits to adopting a certain behavior or else easily fall prey to minimal barriers to participation (p-142)[39].

As Table 1 demonstrates, that a majority of the 47 participants in the study were overweight or obese, predominantly reporting low regularity in high intensity physical activity. Participants' mean baseline BMI was 27 (md = 25.54, sd = 5.49). Mean age was 29.76 years old (md = 28, sd = 7.33). In terms of gaming behaviors, the majority reported cell phones to be their preferred gaming device, and most of them reported playing at least 4-5 times a week. They also preferred social Facebook or mobile games. The preliminary snapshot of data indicates that the sample was largely a likely audience for a game like *SpaPlay*, which incorporates many of the gaming preferences reported by the participants, such as casual gaming on a mobile/social media platform.

**Table 1. Overview of participant breakdown based on their baselines (n=47)**

| | |
|---|---|
| 1. Education level | 52% Undergraduate<br>29% Masters<br>19 % High-school or equivalent |
| 2. Ethnicity | 65% White<br>18% Asian<br>8% Black<br>4% Hispanic |
| 3. Baseline BMI | 15% Normal<br>30% Overweight<br>33% Obese |
| 4. Frequency of intense physical activity | 41% Hardly ever<br>26% At most once a week<br>22% 3-4 times weekly |
| 5. Preferred gaming platform | 75% Cellphone or iPod touch only<br>21% Consoles (Xbox, PlayStation etc.)<br>[illegible] |
| 6. Favorite genre of games | 43% Facebook games<br>40% Mobile games<br>14 % MMORPG |
| 7. Frequency of gaming reported | 52% At least 4-5 times a week<br>22 % 2-3 times a week<br>22% At least once a week |

## 4.2 Descriptive Statistics for Adherence to Game

Using real-time telemetry data from the game, adherence was quantified in three ways. First, we computed the number of days (out of total 90 possible) participants engaged with the game. Any real-time records of log-ins on a given day were used as indicators of engagement. Data showed that participant's mean number of logins was 8.57 (md=2, sd=12.5). Second, to assess regularity of adherence to game play, we computed time intervals between successive days of play for each participant. Mean days between logins served as a measure of the length of time that elapsed between participants' use of the game and an indicator of negative adherence. A summary of all participants' mean length between logins shows mean 24.7 days between logins (md=22, sd=14.23). Standard deviation of days between logins was computed for each individual, and served as a measure of regularity of play. Higher standard deviation indicated highly irregular usage; lower standard deviation indicates more regular usage. Average standard deviation of length between logins for participants was 16.48 (md = 15.16, sd=7.66). Overall, this shows varied but low level of adherence to the game among our participants.

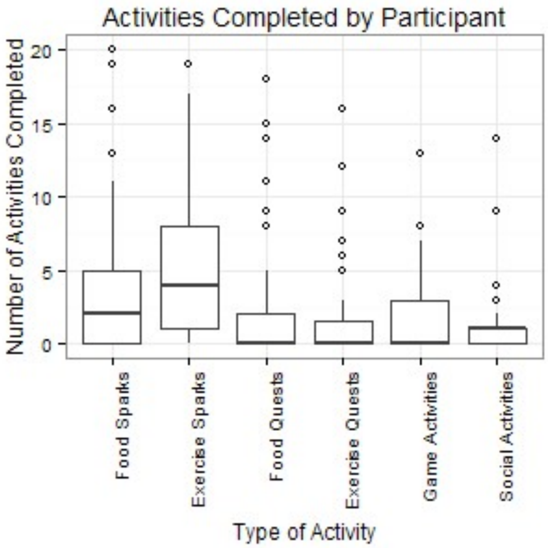


**Figure 3. Shows summaries of the data collected on activities completed by participants within the game, across the 6 categories available.**

Figure 3 shows summary data of gameplay activities with variance. As the figure shows, participants showed a preference for Spark activities. But there is a high level of variability in program utilization as shown in the figure.

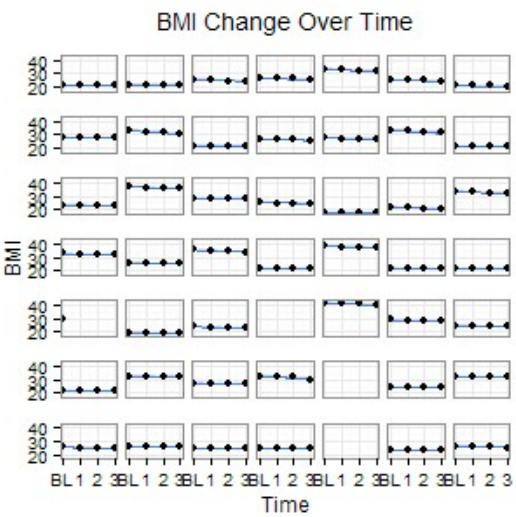


**Figure 4. HLM Results for BMI**

## 4.3 Changes in Health and Motivation Outcomes

Changes in the outcome variables were observed during the course of the study. In particular, there is a significant change in BMI, TTM stage, and Nutrition Knowledge. Change in participants' BMI was shown in almost all cases, as demonstrated through a hierarchical linear model (HLM) in Figure 4. As discussed above, we asked participants to fill in the questionnaires and BMI measures at baseline and once every month. The figure shows the measure of BMI at BaseLine (BL), 1st, 2nd and 3rd measurement time. A one-tailed paired sample's t-test confirms a significant change in BMI, $t(44) = -7.7$, $p < 0.01$. Cohen's d effect size of 1.07 indicates a large decrease in BMI occurred in the course of the study. For Nutrition Knowledge, one-tailed paired samples t-test produces $t(44)=4.28$, $p<0.01$, and Cohen's d of 0.83–a large increase in nutrition knowledge.

As TTM stage changes were non-parametric, Wilcoxon signed rank tests for matched pairs were used. Significant changes were shown in all domains. For Healthy Eating, $V=338$, $p<0.01$; for Physical Activity, $V=351$, $p<0.01$; and for Beverage Choices $V=630$, $p<0.01$.

Furthermore, we used generalized multilevel linear modeling to determine whether or not the changes indicated above were linked to gameplay. For this we used the game play data and looked at correlations between outcomes and gameplay data over time. Figures 5 and 6 show these results for Nutrition Knowledge and BMI.

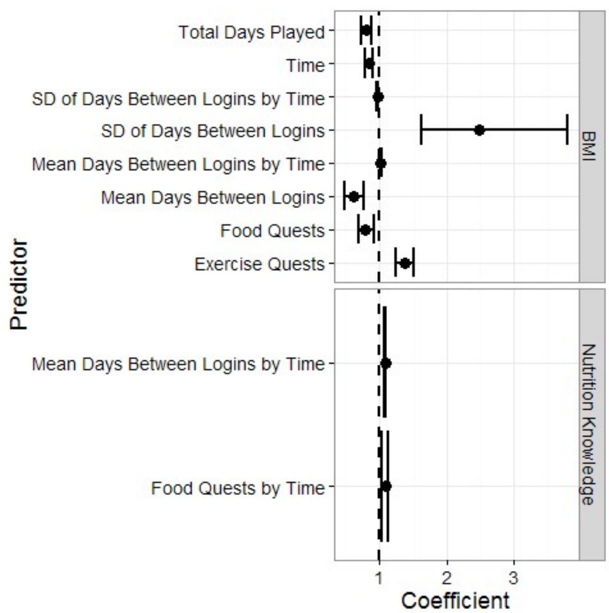


**Figure 5. HLM Results for Nutrition Knowledge**

The included predictors were all variables that were statistically significant for the exploratory analysis ($p< 0.1$) and comprised the final model. The line down the chart (figures 4 and 5) represents the distinction between a positive correlation (right of the line) and a negative correlation (left). The distance of the point from the line represents the coefficient (i.e. the strength of the relationship of the predictor to the outcome), and the error bars represent standard error.

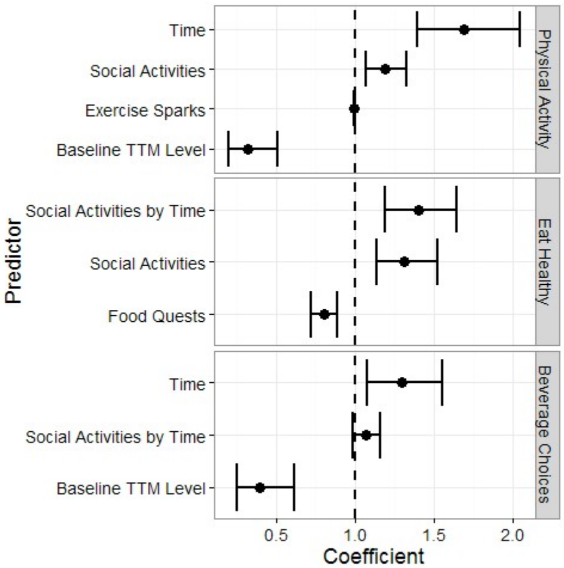


**Figure 6. HLM Results for TTM Stage Change**

In examining the figures, several gameplay activities emerge as significant predictors of all examined outcomes. BMI change was most significantly predicted by SD of days between logins. As negative BMI change indicates weight loss, greater irregularity of game usage was predictive of less weight loss. The results also demonstrate a significant positive effect of Social Activities predicting TTM stage change in physical activity and healthy eating, and a significant interaction effect for social activities and time in beverage choices. These results indicate that social activities within the game predicted a greater likelihood for forward momentum through the TTM stages in the listed domains.

## 5. DISCUSSION

Overall we noticed improvements in indicators primarily external to the game. Results from the analysis indicate that there is shift in TTM stages, NKQ measures and BMI. In other words, as anticipated, and discussed extensively in the literature review sections of this paper, we noticed shifts in cognitive precursors, like their motivation state change, awareness to eating healthy and overall improvements in BMI within the 3 months of the study. Additionally, specific factors from the game were demonstrated to influence these health measures. For instance, we found that engaging in social activities within the game is a significant predictor for motivation state change in physical activity and healthy eating. Again regularity of gameplay was a salient predictor for weight-loss or, in this case drop in BMI values.

Through these findings this paper contributes towards furthering our understanding about design of persuasive media and technologies to promote healthy living. Firstly, these findings indicate that through linking *cognitive precursors*, gameplay data and health outcomes, we are not only able to evaluate the benefit from playing the game, but are also able to refine specific design features in the game. We hope this and similar type of work in the field will facilitate rethinking some of the ways design features can be fine-tuned in games and Apps. Secondly, with this study we have also presented an illustration of a non-traditional methodology for evaluating health games and Apps by integrating behavioral, cognitive and health outcome measures.

However, our study faces several limitations in its current presentation. First, the overall adherence and utilization of the program was low and thus, requires improving some of the critical design aspects in the game. Questions regarding methods for encouraging users to engage with the game on a more consistent basis are yet to be explored, as well.

## 6. CONCLUSION AND IMPICATIONS FOR FUTURE WORK

In conclusion, we argue that pursuing specific measures exclusively, like weight-loss (a health outcome), or cognitive measure, like motivation state, are possibly some of the robust ways to measure the benefits of using health technologies in the short-term. However, behavior change is a complex phenomenon. Thus, it is when we connect several kinds of measures, as has been presented in this paper, we can begin to see which specific features in the game are better predictors for certain behavioral outcomes. Alternatively, we also can reveal the health outcomes that are most sought for in some of the game features, as is the case with beverage choice and social activities in this study. In this way, we become better positioned to strategically predict certain outcomes (for example, dropping out possibilities), or focus on customizing follow-ups through facilitating individuals to cognitively and behaviorally to advance from one motivational stage to another.

For the future, we seek to pursue explanations based on demographic factors and behaviors assessed at baseline to elicit lower adherence values in specific gameplay aspects. Nevertheless, it seems that through playing the game participants' cognitive perceptions or attitudes in terms of drawing attention to what they were eating and how they were exercising changed, in addition to shifts in BMI measures and nutritional knowledge. We wish to highlight that positive changes in health-behaviors and attitudes are crucial first steps towards longitudinal success of any health intervention, especially since it can be challenging to observe these changes in the short term. As a next step in continuing this work, we seek to examine relationships between specific game activity types to cognitive and behavioral outcomes, based on specific sub-groups, such as baseline measures (overweight, obese or normal weight), and demographic measures (education level and ethnicity).

## 7. ACKNOWLEDGMENTS

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