*e*wrapper: Optimizing the use and delivery of engagement strategies in mHealth

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Abstract

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Leveraging built-in mobile functionalities and capabilities, mobile health (mHealth) apps can enable

passive data collection, deliver timely and personalized interventions, and provide anytime/anywhere

accessibility to self-monitoring and self-management tools. Despite these promising developments, the

vast majority of users abandon mHealth apps quickly and after minimal use. To address this issue, we

developed an engagement wrapper (*e*wrapper) designed to increase user engagement in mHealth apps.

*e*wrapper "wraps" around pre-determined, app-specific decision rules and reinforces the target health

behavior(s) by strategically employing various transdisciplinary engagement strategies. The overarching

goal of *e*wrapper is to optimize the operationalization of engagement strategies by determining which

strategies work for whom, when, and under what conditions. My thesis provides: 1) a review of

literature on user engagement; 2) an introduction to the design of *e*wrapper in the context of a self-

monitoring dietary intake mobile application; 3) findings and implications based on user evaluations.

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1. Introduction

Despite high rates of reported receptivity to (Makovsky Health, n.d.) and perceived usefulness of (Krebs and Duncan, 2015) mobile health (mHealth) applications, the vast majority of users disengage quickly and after minimal use (e.g., Asimakopoulos and Asimakopoulos, 2017; Grist and Porter, 2017; Ledger and McCaffrey, 2016; Shih et al., 2016; Clawson et al., 2015; Epstein et al., 2015; Gouveia et al., 2015; Lazar et al., 2015; Shih et al., 2015; Klasnja et al., 2011; Eysenbach, 2005). For researchers and mHealth developers, this is particularly problematic as it is often difficult to assess the true effectiveness of interventions if a large percentage of users abandon the applications prior to the possibility of experiencing their intended therapeutic effects.

The most common reasons for disengagement as reported by users, include: 1) burden of manual data entry; and 2) loss of interest (Epstein, 2016; Cordeiro, 2015; Krebs and Duncan, 2015). Many researchers point to the general lack of/need for design considerations to accommodate individual user differences (e.g., level of motivation), preferences, and related contextual factors (Rapp et al., 2018; Sarsam and Al-Samarraie, 2018; Nacke and Deterding, 2017; Rooksby et al., 2014; Steichen et al., 2013). That is, mHealth interventions are often designed using a "one size fits all" approach – all users exposed to the same content, strategies, and formatting (Fleming et al., 2016). As a result, researchers and developers have begun implementing more adaptive and individualized intervention designs and engagement strategies (Orji and Moffatt, 2018). These recent efforts have demonstrated some promise; however, adaptive designs and integrated engagement strategies have yielded a new set of challenges. Namely, the design approaches and frameworks often lack a theoretical framework (Orji and Moffatt, 2018; Seaborn and Fels, 2015) and consequently, there is limited insight into the isolated effects of individual strategies and the collective effects of integrated strategies (let alone how contextual factors mediate these effects) (Grutzmacher et al., 2019; Orji and Moffatt, 2018; Rapp,

2018). This phenomenon has been referred to as the "black box" as the effects of the strategies tend to be confounded (Oinas-Kukkonen, 2013; Landers et al., 2019).

To overcome the aforementioned challenges, there is a tremendous need for theoretically-driven frameworks to guide the design and operationalization of engagement strategies in mHealth settings (Orji and Moffatt, 2018; Ryan et al., 2018; Yeager and Benight, 2018). This is precisely the motivation behind the current project: to develop a theoretically-driven framework (Wagner et. al, 2017) that strategically ties a collection of transdisciplinary engagement strategies into a coherent and cohesive system (*e*wrapper) that can be integrated with any existing or future mHealth application. *e*wrapper is designed to "wrap" (engagement strategies) around pre-determined, app-specific decision rules to reinforce target health behavior(s). The engagement strategies in *e*wrapper target varying states of cognitive processing (i.e., automatic versus deliberative), as well as different types and levels of motivation (i.e., intrinsic versus extrinsic), and adapt over time to accommodate user preferences and characteristics to optimize delivery, and maximize the effects of the engagement strategies – ultimately determining which strategy works best for whom, when, and under what conditions.

In this thesis, I aim to understand user perceived needs and preferences to various engagement strategies employed in *ewrapper.* Specifically, a pilot user study was conducted with half a dozen participants to evaluate a paper prototype version of *e*wrapper integrated with a self-monitoring dietary intake application. Key findings from this study suggest notable heterogeneity in the needs and preferences between individuals with low versus high commitment. This supports the need for an adaptive system – meeting individuals where they are at and providing tailored strategies for increasing and sustaining engagement, and ultimately, facilitating behavior change.

2.   Literature review

2.1 Defining user engagement

Researchers and developers alike are hell-bent on increasing their understanding of user engagement, and how it can be most effectively measured and manipulated. However, a significant impediment remains that may be thwarting progress- *how should user engagement be defined*? There is a general lack of consensus across disciplines on how to best conceptualize and define user engagement, which has significant implications as technology and our relationship to technology continues to evolve (Attfield et al., 2011; Doherty and Doherty, 2018). There are two variant definitions or conceptualizations of user engagement that appear most frequently across literatures. In the behavioral and social science literature (Perski et al., 2017), engagement is mainly conceptualized as a temporal construct measured by usage, which includes both frequency and extent of use; whereas literature in Human-Computer Interaction and Computer Science more broadly, tends to conceptualize engagement as temporal states of "flow", which is defined as an intently focused and subjective mental state that fosters feelings of elation (Peters, Castellano, and de Fritas, 2009; Doherty and Doherty, 2018; Bouvier, Lavoue, and Sehaba, 2014; Csikszentmihalyi, 1990).

Perhaps as an attempt to bridge the aforementioned conceptualizations of user engagement, Yardley et al. (2016) posits a conceptualization that acknowledges both perspectives and does not consider them mutually exclusive. Specifically, Yardley et al. delineates user engagement on a micro and macro level. Micro-level user engagement is conceived as a "moment-to-moment" state (similar to "flow"); whereas macro-level user engagement is more temporally based as it encompasses user progress and activity related to the overarching objectives or goals of the intervention. This multidimensionality-based conceptualization of engagement has been detailed elsewhere in the literature. For example, O'Brien and Toms (2008) postulate that engagement involves the interplay of several dimensions (e.g., affect,

perceived control, awareness, and motivation) and is *fluid*, whereby users oscillate between varying degrees of engagement (including, at times, disengagement and re-engagement). And, Perski et al. (2017) describe engagement as multidimensional and *dynamic* – varying "both within and across individuals over time."

2.2 Measuring user engagement

Effectively measuring user engagement can be challenging given its *dynamic and multifaceted nature*. In order to more fully understand and *evaluate* user engagement, it is important to consider the use of both *objective* and *subjective* measures (Yardley et al., 2016; Hekler, 2013): *objective measures* may include sensory data (e.g., location/context, user's physical state (e.g., sleeping, sitting, driving, running, etc.), device usage (e.g., frequency and time points of use), and/or paradata (i.e., in-app/intervention activity tracking, which may include clicks, usage time stamps)); *subjective measures* may include ecological momentary assessments (i.e., capturing self-reported data in-the-moment/real-time) and/or qualitative data collection (e.g., conducting post-intervention use interviews or focus groups). The *coupling of objective and subjective measures* aids in facilitating deeper insight and provides a more coherent and reliable understanding of user behavior and engagement. For example, if a user's activity level with an intervention begins receding as detected by an objective measure, this may signal to the researcher intervention decay or dissatisfaction; however, upon the use of a subjective measure (e.g., interviewing the user) the researcher learns that the user has mastered the target behavior and no longer relies on the intervention for feedback or prompting. It is interesting to note that this scenario substantiates some of the criticism related to defining engagement solely based on usage (Yardley, 2016). Nevertheless, the use of coupling methods can increase reliability of results and can provide behavioral and attitudinal user insights that otherwise cannot be captured with use of a single, independent method.

2.3 Engagement challenges in mHealth

Though many report having downloaded mHealth apps, sustained usage of these apps has been disappointingly low. Nearly 80% of users abandon mobile apps within 3 days of use; and within 3 months the rate of attrition climbs to 95% (Andrewchen.co., 2016). Low use and high attrition rates have been evidenced across most all domains of health behavior interventions (Kohl et al., 2013). In most clinical trials, typically only participants with intention and relatively high motivation to engage in the target health behavior are included in studies. Unfortunately, even in these settings, significant levels of low use and attrition are observed (Eysenbach, 2005).

Attrition also has a significant effect on clinical studies that rely on study participants to complete pre- and post-trial assessments. A common strategy to overcome attrition in this setting is to offer study participants sizable financial incentives to engage in and complete studies (Grenard et al., 2013). This strategy, however, has substantial drawbacks. First, it may introduce a confounding variable as study participants' motivation to engage in and complete studies may be more driven by monetary rewards than motivation for behavior change. Ostensibly, this poses a real threat to the internal validity of these studies. And perhaps most importantly, this "solution" likely cannot be translated or replicated in a "real-world" setting (i.e., absent of assessments and monetary incentives). Furthermore, monetary incentives are not a long-term solution to maintaining engagement as Ryan and Deci (2000) found that monetary rewards are only effective in the short-term.

There is a paucity of extant research investigating the antecedents of attrition. One study found that the most commonly reported reasons for disengagement were related to the burden of manually self-reporting data (e.g., logging food items in self-monitoring apps) and general loss of interest in the application (Krebs and Duncan, 2015). Moreover, Blanson Henkemans et al. (2011) identified three determinants of attrition in the context of an online lifestyle diary with a personal computer assistant- 1)

locus of control: Individuals with external locus of control were more likely to drop out of study as compared to individuals with internal locus of control; 2) *cognitive abilities:* Individuals with low cognitive abilities (as determined by scores on a vocabulary test) were more inclined to drop out of the study as compared to individuals with high cognitive abilities; and 3) *motivation to perform self-care*: Individuals with low levels of motivation to engage in self-care practices were more likely to drop out of study as compared to individuals that were more highly motivated to perform self-care.

It is important to note that not all cessation of mHealth interventions can be interpreted as a negative outcome. For example, in some instances, disengagement (as described earlier) can be explained by proficiency or maturation in the target health behavior in which case continued use of the app is no longer needed. Similarly, retention or sustained engagement cannot always be interpreted as a positive outcome as some individuals may be overly dependent on the application or intervention, which could undermine both self-regulation and self-efficacy (Yardley, 2016).

2.4 Promise in mHealth

Digital technologies have the potential to increase the reach, quality of care, and cost-effectiveness of current models of healthcare delivery (Kumar et al., 2013). Moreover, emerging technologies foster the potential for developing new models of healthcare both *within* and *outside* formal systems of service delivery. For example, these technologies can embolden patients to assume a more proactive role in their personal health care. The mobile platform, in particular, provides exciting possibilities for the promotion of health behaviors through mHealth applications and interventions. Leveraging built-in mobile functionalities and capabilities, mHealth tools can collect one's *passive data* (e.g., physical activity, context/location), deliver *timely* and *personalized interventions*, and provide *anytime/anywhere* accessibility to *self-monitoring and self-management tools* (e.g., blood glucose levels, physical activity, diet, and weight can each be tracked for diabetes management). In addition, *moment-to-moment*

patient health data can be extracted from patient-owned technologies, such as mobile devices, which can provide researchers and practitioners with rich and objective insight into patient behavior – a significant advancement compared to traditional, subjective means of collecting these data via self-report (Kumar et al., 2013).

Moreover, given the ubiquity of smartphone owners (by 2020, 80% of Americans are projected to own a smartphone; eMarker/Statista, n.d.), an increasing number of individuals can be reached, including populations that have been largely marginalized or underserved by traditional health care service delivery systems. Furthermore, Americans, by and large (66%), have a favorable outlook and are receptive to the use of mobile technologies and wearables to supplement their health care (Makovsky Health, n.d.). According to a recent national survey study conducted by Krebs and Duncan (2015), nearly 60% reported downloading at least one mHealth application, and 40% reported downloading over five mHealth applications. In addition, the survey participants indicated high rates of perceived *effectiveness of the mHealth applications*: ~60% reported that their health was "Little/somewhat improved," and ~30% reported that their health "Very much improved." A wide range of clinical trials has evaluated the effectiveness of mHealth interventions and corroborates these findings. For example, mHealth interventions have demonstrated effectiveness in increasing prevention and self-management in diseases such as diabetes, HIV, asthma, depression (Kitsiou, 2017; Cole-Lewis and Kershaw, 2010; Free et al., 2013; Ostojic et al., 2005; Schlosser, 2017); smoking cessation (Free et al, 2013); self-monitoring and weight loss (Turner-McGrievy, 2013); and increasing physical activity (Hurling et al., 2007).

The benefits of mobile technologies for health promotion extend beyond the user-level. The massive troves of user data serve as an invaluable source of insight into human behavior, as well as the relationship between human behavior and mobile technologies. Researchers, clinical providers, health care companies and the alike are able to use the data to improve health practices and treatments, and

better address user needs and preferences – the ultimate goal being the development of interventions that are tailored to the individual user, and delivered in a timely manner (e.g., when the user is most receptive to or in need of an intervention).

2.5 mHealth frameworks for user engagement

An extensive literature review on *engagement in mHealth settings* conducted by Perski et al. (2017) uncovered several recurring predictors of engagement (i.e., certain aspects or components of existing mHealth interventions found to be positively correlated with engagement):

- *motivation* (i.e., internal drive to change behavior or achieve a certain outcome);

- *expectations* (i.e., alignment between the goal of the mHealth intervention and user's expectation);

- *social support and social influence* (i.e., facilitating opportunity for interacting with others, as well as peer-to-peer or team-based competitions (e.g., leaderboards and ranking systems);

- *reminders* (i.e., push notifications prompting user to engage with a mHealth intervention and/or perform a target behavior);

- *control features* (i.e., instilling a sense of user autonomy by providing choices or options regarding how one wishes to engage with or use a mHealth intervention);

- *novelty* (e.g., regularly providing or offering new content); and

- *personalization* (i.e., content tailored specific to an individual user's needs, interests, and/or preferences).

Moreover, *incentive structures* and *reward systems* grounded in behavioral economics theory have also evidenced promise in predicting engagement behavior and facilitating behavior change. For example, the phenomenon of loss aversion (Tversky and Kahneman, 1991) – people's tendency to be more driven to avoid loss as compared to being driven to obtain a gain of equal value – has been proven to be an

effective strategy. Volpp et al. (2008) found that employing loss aversion strategies in a weight loss study increased the likelihood of behavior change as compared to a control condition. Specifically, two distinct loss aversion strategies evidenced significant effectiveness in study participants' ability to lose weight – a lottery system group (participants that achieved their weight goal were entered into a daily lottery for a chance of winning a monetary reward) and a deposit contract group (participants invested personal money that would be lost if weight goals were not achieved). Both groups lost significantly more weight than the control group. Moreover, the *timing* of receiving rewards has also been shown to be a predictor of engagement. Woolley and Fishbach (2017) found that *immediate rewards* are more predictive of long-term engagement and goal achievement than delayed rewards.

Several of the aforementioned predictors of engagement have been harnessed in innovative and integrative ways in the ever-evolving and sprawling domain of *gamification* – defined as "the use of game design elements in non-game contexts" (Deterding, et al., 2011). Integrating and leveraging game design elements (e.g., point systems, badges, leaderboards, avatars, etc.) in settings such as mHealth to increase motivation and promote behavior change has yielded generally mixed results (Johnson et al., 2016, Hamari et al., 2014). There are several "usual suspects" that have been attributed to these findings. Firstly, the vast majority of gamification research has been guided in the absence of theoretical considerations (Seaborn and Fels, 2015). Secondly, there is a remarkable dearth of rigorous research that has investigated the role(s) of individual game elements and their true effects on motivation and behavior outcomes (Mekler et al., 2015, Johnson et al., 2016); not to mention how these effects are mediated by contextual factors and individual user characteristics (Sailer et al., 2017, Nacke and Deterding, 2017). Thus, evaluating frameworks without an understanding of the effects of the individual elements is no more productive or telling than the evaluation of a single strategy (Hamari et al., 2014; Seaborn and Fels, 2015). Next, there exists profound heterogeneity in regard to the methods and measures used for evaluative purposes; thus, outcomes cannot be sufficiently compared (Nacke and

Deterding, 2017). Finally, there is a paucity of extant gamification research that has focused on intrinsic motivation outcomes, as the focus has been primarily fixated on extrinsically motivated behavioral outcomes (Hamari et al., 2014; Seaborn and Fels, 2015; Alahäivälä and Oinas-Kukkonen, 2016). In all, there is a paramount need for theoretically-driven frameworks in which strategies can be individually, as well as collectively (or dynamically) operationalized and evaluated; and more strategies to increase intrinsic motivation need to be considered to advance this research and increase the prospect of sustaining engagement and facilitating behavior change.

2.6 *e*wrapper framework and design

In attempt to address the aforementioned issues we developed *e*wrapper, a theoretically-driven framework to operationalize and evaluate a collection of transdisciplinary (e.g., HCI, business/marketing, cognitive psychology, social psychology engagement strategies) (Wagner et al., 2017). *e*wrapper is an ambient display designed to be integrated with *existing and/or future mHealth applications* by "wrapping" around pre-determined, app-specific decision rules to reinforce/promote the target health behavior(s) (see *Figure 1* below for a breakdown of several of the strategies and how they were operationalized in the context of a dietary self-monitoring intervention).

2.6.1   Goal of *e*wrapper

ENGAGEMENT STRATEGY	DEFINITION	OPERATIONALIZATION
Pre-set goals	Goals created by the individual, in an attempt to reach a desired outcome (Locke and Latham, 1990)	Example: Self-monitor 2 eating episodes daily
Personalized feedback	Information specific to the user's previous behavioral patterns (Carver and Shieier, 1981; 1982)	Progress charts; positive reinforcement messaging
Normative feedback	Making behavioral patterns of a reference group salient or emphasizing differences between the individuals' behavior and the most common behavior in a salient reference group (Goldstein, Cialdini, and Griskevicius, 2008)	On occasion, participants may receive the following types of messaging: Individual vs. team performance; Team vs. team performance

Rewards	Reinforcement of a given behavior through material goods (various types) (Ferster and Skinner, 1957; Volpp et al., 2008)	Ostrich feather growth; points; mystery eggs
Distraction	Shifting thoughts away from the current mental state (Dekker et al., 2009)	Consuming contents of mystery eggs
Uncertainty	Using lack of knowledge and inability to predict future events; inconsistency (Milliken, 1987)	Contents of mystery eggs; Ostrich feather growth
Scarcity	Limiting the supply or duration of availability of a given resource (Cialdini, 2001)	Mystery eggs only available for 24 hours
Reciprocity	Capitalizing on shared efforts, cooperation, or the tendency for individuals to return favors (Gouldner, 1960)	Certain mystery eggs can be shared with/received from teammates
Goal-gradient	Endowing or creating the illusion of progress towards a goal (Hull, 1932)	Adjusted point system to make unlocking mystery eggs more attainable; no-strings attached points

Figure 1. *e*wrapper engagement strategies operationalized in the context of a self-monitoring dietary intake

The *e*wrapper project is an extension of Inbal Nahum-Shani's work on *just-in-time adaptive interventions* and the optimization of use/delivery of interventions and intervention components (Nahum-Shani, 2015). In the context of *e*wrapper, the goal is to determine the optimal conditions for operationalizing a collection of engagement strategies at the individual user level. To help guide the employment of the strategies in terms of determining optimal conditions of use, a 2 x 2 conceptual framework was developed (Wagner et al., 2017) and the strategies were organized according to their target: 1) state of cognitive processing- *automatic* (nonconscious, minimal cognitive effort) versus *deliberative* (conscious, requires cognitive effort); and 2) type and level of motivation- *intrinsic* (internally derived goal/purpose) versus *extrinsic* (externally driven goal/reward). This framework can help determine optimal (or testable) conditions for the use and delivery of the strategies and can serve as a useful conceptual model for more nuanced interpretations of the proximal and distal engagement outcomes. To assess the effectiveness of *e*wrapper, in terms of its effect(s) on engagement levels, the target behavior needs to be clearly defined and measured. For our initial evaluation, we integrated *e*wrapper with a self-monitoring dietary intake mobile application where user engagement can be clearly defined and cleanly/objectively measured: did the user self-monitor their dietary consumption or not. Specifically,

the target health behavior prescribed to users in the mobile application is to self-monitor *at least two eating episodes* per day. An eating episode in this context is defined as any food or drink consumed in a single sitting.

2.6.2   Engagement strategies used in *e*wrapper design

In this subsection, the engagement strategies used in *e*wrapper are organized according to their placement within the 2 x 2 framework (i.e., cognitive processing: automatic vs. deliberative; and motivation: intrinsic vs. extrinsic motivation); and how they are operationalized, and expected outcomes are elucidated.

I. Extrinsic and deliberative strategies

These strategies are expected to generate extrinsic motivation for engagement by capitalizing on processes that are more deliberative in nature (i.e., conscious, require cognitive effort, verbal, and typically slow).

Goal setting

Goal setting is defined as the establishment of personal goals to achieve a desired outcome (Locke and Latham, 1990). Users are asked to follow a simple and realistic goal of self-monitoring 2 eating episodes per day, and within 1 hour of consumption. We define eating episodes as any food or drink consumed within a single sitting.

Expected outcome: Establishing and agreeing to clear daily target behaviors at the onset can increase adherence and help facilitate habit formation.

Personalized feedback is centered on goal attainment and takes shape in three distinct forms. First, the ambient display in *e*wrapper includes an *ostrich* that serves as a coach or guide throughout the duration of app use. The ostrich is responsible for delivering points, messaging, and reminders (see *Figure 2*).
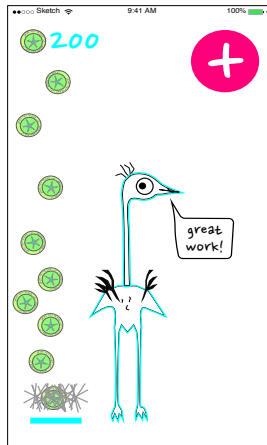

Figure 2. *Personalized feedback* is delivered via the ostrich. This includes: points, messaging, and reminders

- *Points:* Following self-monitoring of an eating episode, the ostrich awards users with points that aggregate and unlock various rewards (described below).

  Expected outcome: Points serve as a symbolic representation of progress towards the users' goals, and can increase users' perceived sense of achievement and competence.

- *Messages:* On occasion, following self-monitoring, the ostrich provides users with personalized feedback messages, which highlight user performance statistics (e.g., number of consecutive daily goals accomplished), as well as next objectives (e.g., how many points needed to unlock the next reward).

  Expected outcome: Message-based personalized feedback is a direct/explicit signal of users' progress towards goals. When the feedback is perceived as positive progress this can increase users' perceived competence (increasing or maintaining adherence); or if perceived as neutral or declining progress, this can increase users' motivation to pick up the pace (increasing engagement/adherence).

- *Reminders:* The ostrich occasionally sends reminders in the form of push notifications if no self-monitoring is detected within a specified time interval. Specifically, there are two possible time

points in which users could receive a reminder. The decision points are structured around a 14-hour day- *Time point 1:* if users have yet to self-monitor between wake up and 6 hours post-wake up, a reminder from the ostrich may be delivered to users; *Time point 2:* if users have yet to self-monitor two eating episodes (i.e., daily goal) between wake up and 13 hours post-wake up, a reminder from the ostrich may be delivered to alert users that only 1 hour remains to self-monitor anything consumed that day.

Expected outcome: Reminders are expected to increase or help maintain adherence to users' goals.

The second form of personalized feedback is represented in ostrich feathers, which grow upon attaining daily goal (i.e., self-monitoring 2 eating episodes). Upon downloading the app, the ostrich starts out featherless (naked) and as users attain daily goals, feathers gradually fill in over time (*see Figure 3*).

Expected outcome: Ostrich feather growth serves as a symbolic representation of progress towards the users' long-term goals and is expected to increase users' perceived sense of achievement and competence.
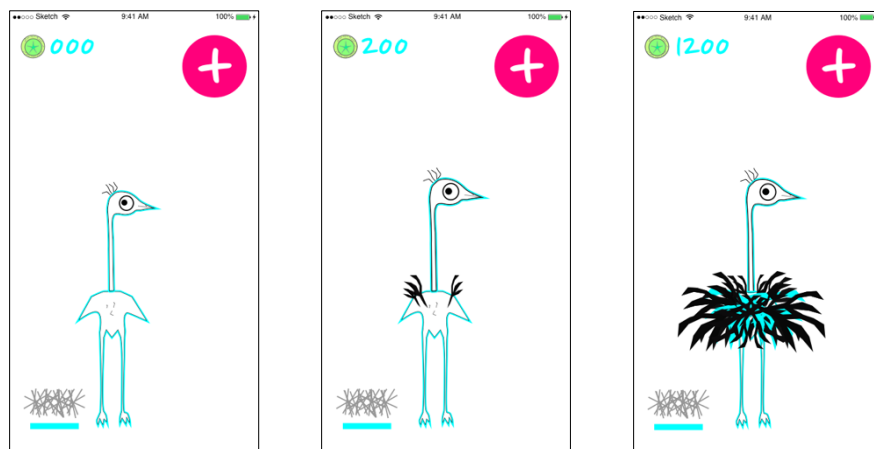

Figure 3. *Personalized feedback* is also represented symbolically via the growth of ostrich feathers. The ostrich grows a few feathers upon attaining daily goal.

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Finally, the third form of personalized feedback is presented as rewards – monetary and non-monetary – to reinforce engagement (i.e., the goal of self-monitoring eating episodes within one hour of consumption). The rewards are operationalized via a point system. Points are awarded following the self-monitoring of an eating episode. Self-monitoring outside of 1 hour of consumption, results in a significant reduction in the value of points awarded. Awarded points aggregate throughout the duration of app use, and as certain point thresholds are crossed, different kinds of rewards in the form of eggs are unlocked. There is a total of 5 different kinds of eggs to unlock. An unlocked egg is made available as a possible reward for future self-monitoring. Awarded eggs appear in the ostrich nest (see *Figure 4*). Each kind of egg contains a unique type of content- 1) Orange egg: humor based media (e.g., viral memes, gifs); 2) Green egg: did you know (e.g., interesting facts, life hacks); 3) Blue egg: inspirational content (e.g., quotes or mantras); 4) Golden egg: small monetary rewards (e.g., $2 credit to Amazon); and 5) Purple egg: random mixture of contents listed above, and this egg can be shared with others, as explained in more detail below under the "Giving" engagement strategy.

Expected outcome: Unlocking the various kinds of rewards serves as a symbolic representation of progress towards the users' long-term goals, and this is expected to increase users' perceived sense of achievement and competence, which in turn can increase intrinsic motivation, which is essential for long-term engagement. Moreover, not knowing what locked eggs contain and/or the contents of awarded eggs is expected to pique curiosity resulting in increased engagement (particularly at time points in which a point threshold to unlock an egg is in reach). Earning rewards can also increase users' perceived sense of achievement and competence.
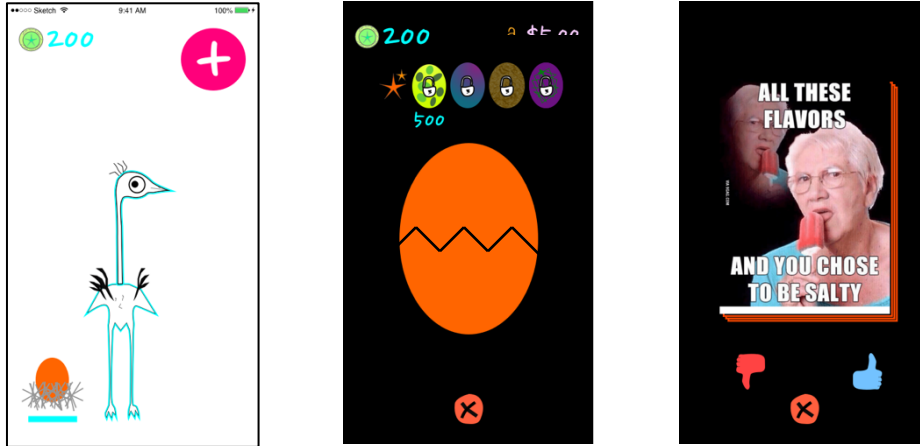
Figure 4. Unlocking *Rewards* serves as a symbolic representation of progress and earning unlocked rewards can increase competence and sense of achievement. Eggs are occasionally awarded for self-monitoring.

II. Extrinsic and automatic strategies

These strategies are expected to generate extrinsic motivation for engagement by capitalizing on processes that are more automatic in nature (i.e., nonconscious, intuitive, associative, nonverbal, emotional, and typically fast).

Normative feedback

Normative feedback is provided to apprise users on how their performance compares to a salient reference group (Cialdini et al., 2008). During onboarding of the app, users select a team from three different colored ostriches; the color of ostrich selected represents the team that users will cooperate/compete with (i.e., salient reference group) for the duration of app use. As noted earlier, the ostrich serves as a coach or guide throughout the duration of app use and is responsible delivering, on occasion, normative feedback upon self-monitoring. Types of normative feedback messaging include: 1) user's performance versus teammates' performance (e.g., "You achieve your daily goal an average of 68% of week days, your teammates' average 74%"); as well as 2) user's team performance versus the other teams' performance (e.g., "Your team can overtake the top spot if 90% of your team logs once more today!"). Normative feedback is also leveraged in the form of reminders. For example, users could

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receive a message such as the following: "85% of your team logged at least once today. Log now to catch up!"

Expected outcome: Normative feedback is expected to influence users to engage based on the reported performance/progress of their teammates. That is, if user's performance/progress is trailing teammates (but not out of reach) motivation is expected to increase; and if user's performance/progress is leading teammates, motivation is expected to persist to maintain lead.

Scarcity

To make the rewards more attractive (Cialdini, 2001), awarded eggs are only available for a limited time, disappearing after 24 hours if not redeemed. To increase the saliency of this strategy, the egg begins to fade in appearance and pulsate as it nears the expiration mark. In addition, on occasion, users will receive a push notification reminding them of their egg's impending expiration.

Expected outcome: Scarcity of rewards (earned or received from teammate) is expected to increase proximal engagement and/or facilitate re-engagement – drawing users back into the application to redeem the reward. Moreover, if users find the reward contents to be satisfying, it can increase their motivation to (continue) engaging in self-monitoring to earn or unlock additional rewards.

Loss-averse messages

To leverage people's general preference of avoiding losses to increasing gains (Tversky and Kahneman, 1991), we included messages that highlight the points or rewards users could have earned had they attained their daily goal, with emphasis on what can be earned (or lost again) the following day.

Expected outcome: Loss-averse messages are expected to increase users' motivation to engage in self-monitoring to avoid future losses (i.e., attaining the following day's goal).

Goal-gradient

We used two approaches to capitalize on people's tendency to expend more effort as they approach a reward (Hull, 1932; Kivetz et al., 2006). First, to increase engagement among low-engaged users, the points needed to unlock the next egg in line are reduced as soon as signs of waning engagement are detected (i.e., as evidenced by self-monitoring activity (or lack thereof)). In other words, unlocking the next egg in line is made more attainable for users showing signs of low engagement. Users are not made aware of the point adjustment. Second, boosters are provided to re-engage users who show signs of disengagement. Specifically, "no strings attached" booster points are delivered to users via push notification if no self-monitoring is recorded within a 48-hour period. The booster points will move the user closer to unlocking the next egg.

Expected outcome: Goal-gradient is expected to increase users' perceived sense of competence and in turn increase motivation to continue engaging (or to re-engage) to unlock reward.

III. Intrinsic and deliberative strategies

These strategies are expected to generate intrinsic motivation for engagement by capitalizing on processes that are more deliberative (i.e., conscious, require cognitive effort, verbal, and typically slow).

Giving

Giving facilitates positive emotions through benevolent behaviors (Brown et al., 2003). The last egg users unlock is the kind of egg that can be shared with a teammate.

Expected outcome: Giving is expected to foster positive affect in users and increase their sense of connectedness, which in turn could increase their motivation to continue engaging/contributing.

Distraction

Distraction is defined in terms of shifting one's internal focus away from negative thoughts or emotions (Dekker et al., 2009). The content selected for each kind of fruit is intended to elicit positive emotion and be desirable to seek out as a form of entertainment and/or as a means to escape reality.

Expected outcome: Self-monitoring can stir up negative or unwanted feelings. By providing opportunities for distraction (which increases positive affect) following self-monitoring is expected to help offset any negative or unwanted feelings in that moment, as well as disrupt/weaken any memory association linking self-monitoring to the negative or unwanted feelings.

IV. Intrinsic and automatic strategies

These strategies are expected to generate intrinsic motivation for engagement by capitalizing on processes that are more automatic (i.e., nonconscious, intuitive and associative in nature, nonverbal, emotional, and typically fast).

Uncertainty

Uncertainty refers to the inability to predict outcomes as a result of one's actions (Milliken, 1987). Uncertain events evoke more intense emotions than predictable ones; thus, uncertainty can increase desirable pleasure (Wilson et al., 2005). Uncertainty is operationalized in the following ways:

- *Ostrich maturity:* Users are not able to anticipate when the ostrich will mature. At the onset of using the app, the ostrich starts out as a baby and with time gradually matures into an adult. Ostrich growth serves as a visual representation and reminder of progress towards users' long-term goals.
- *Feather growth:* Users are not able to anticipant the shape and form of the feathers that grow upon completing daily goals.

- *Locked eggs:* The kind of content each egg provides is a mystery to users until the egg is

  unlocked.

- *Earning eggs:* A lottery system is implemented whereby each time users self-monitor within 1

  hour of consumption, they have a certain chance of earning an egg. In other words, engagement

  does not always lead to the earning of an egg. Adding variation in terms of when users are

  awarded eggs increases anticipation and curiosity.

- *Kinds of eggs & contents of eggs:* Each time an egg is to be awarded (not unlocked), the kind of

  egg is selected randomly from the eggs that have been unlocked. Moreover, the content

  contained within the eggs is always fresh (never recycled).

Expected outcome: Uncertainty is expected to reduce boredom and habituation, as well as increase

curiosity.

<u>*Reciprocity*</u>

Reciprocity leverages people's tendency to feel obligated to return a favor (Gouldner, 1960). Shareable

eggs can activate reciprocity upon users receiving an egg from teammates.

Expected outcome: Receiving a "no strings attached" reward, such as an egg shared by a teammate, is

expected to increase users' motivation to return the gesture and thereby enhance engagement.

2.6.3   Components of self-monitoring dietary intake application

The self-monitoring dietary intake application in which *e*wrapper is integrated with, is comprised of two components: 1) Food/drink *self-monitoring tool* (see *Figure 5*); and 2) daily calorie consumption "calorie ring" *data visualization* (see *Figure 6*). All other features (i.e., discussed in *Section 3.2*) are part of *e*wrapper application. Both applications are seamlessly integrated into a single working system – perceived by users as a single application.
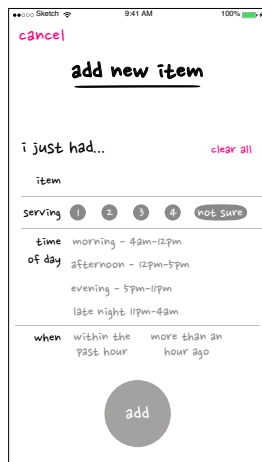
Figure 5. Self-monitoring tool screen

Figure 6. "Calorie ring" data visualization screen

3.   User study

3.1 Goal of user study

The goal of the user study was to: 1) develop an understanding of participant experience and usage of mHealth applications for self-monitoring or tracking a behavior(s) and associated barriers; 2) conduct a "think-aloud" usability exercise with a paper prototype of *e*wrapper and solicit feedback about the use and delivery of various engagement strategies within *e*wrapper.

3.2 Methods

3.2.1   Participants

A convenience sample of six participants was recruited for semi-structured interviews. Four of the

participants were undergraduate students at the University of Michigan (all female; ages 19-22); one

participant was a non-traditional undergraduate student at Washtenaw Community College (male; age

30); and one participant was a graduate student at the University of Michigan (male; age 23). The only

inclusion criterion was for participants to have at least some experience using a mobile application for

self-monitoring or tracking a behavior (see *Figure 7* for a breakdown of participant prior usage of mobile

applications for self-monitoring or tracking of a behavior(s)). The semi-structured interviews ranged in

duration from 40-84 minutes. Participants were compensated with a $30 Amazon e-gift card.

	Behavior monitored	App used	Goal	Period of use	Reason for abandonment
P1	Dietary intake	MyFitnessPal	Increase awareness of diet	~4-6 weeks	Too much effort involved in logging
P2	Dietary intake	MyFitnessPal	Increase awareness of diet	~6-8 weeks	Too much effort involved in logging
P3	Attention during tasks	Forest	Increase productivity	~3 months	Provided two possible reasons: a) limitation of not being able to check phone or it would kill tree; b) no longer needed app to stay on task
P4	1) Dietary intake; 2) Step count	1) SlimFast; 2) Coinbase	Lose weight (goal for both apps)	1) ~6 months; 2) ~3 months	1) Too much effort involved in logging; 2) Too much effort required to earn rewards
P5	Step count	WeChat; MyHealth	Personal gratification	1+ year	1) N/A; still uses; 2) N/A; still uses
P6	1) Dietary intake; 2) Step count; 3) Sleep; 4) Water intake	Fitbit (used for all behaviors)	Gain weight; 7+ hours of sleep per night	1+ year	N/A; still uses

Figure 7. Participant (P1-P6) breakdown of prior use of mobile applications for monitoring or tracking of a behavior.

3.2.2   Procedure

All interviews were facilitated by a graduate student researcher (myself) and the initial two interviews

included an undergraduate research assistant. The interviews were all conducted in a conference room

at the University of Michigan Institute for Social Research and audio recorded with participants' verbal

consent. The interviews were comprised of two phases: 1) participant reflection on their own prior

experience using a mobile application for monitoring or tracking a behavior; 2) "think aloud" usability

exercise (Ericsson & Simon, 1998) with *e*wrapper in the context of a self-monitoring dietary intake

mobile application, and discussion about the components and related engagement strategies within

*e*wrapper.

Phase I: Participant reflection on prior experience using a mobile application for monitoring or tracking a

behavior: At the outset of the interview, participants were asked to draw on a whiteboard what they

remembered about the mobile application they used for monitoring or tracking a behavior, and to

describe their experience and usage of the application. Usage included inquiries about frequency of use

(i.e., time per day or week); consistency of use (engaging in behavior to use of application); time of use

(e.g., after engaging in the behavior or before bed); and if no longer using the app, period of use (i.e.,

time between first use and cessation). Participants were then asked about internal and external

facilitators, as well as internal and external barriers associated with the application. If participants were

no longer using the application, they were asked about reasons for cessation.

*Phase II: "Think-aloud" usability exercise with e*wrapper *and discussion about the components and*

*related engagement strategies within e*wrapper*:* The next phase of the interview involved an initial

usability exercise with paper prototypes of the *e*wrapper interface design in the context of a self-

monitoring dietary intake mobile application. The distinction between *e*wrapper and the self-monitoring

application was not explained to participants, as the inherent goal of *e*wrapper is to seamlessly integrate

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with mobile applications. That is, *e*wrapper is intended to "wrap" around applications, and the

engagement strategies are tailored to the existing decision rules of these applications – perceived as a

single application to users.

Participants were instructed to "think-aloud" as they performed a task, and to share anything/all that

came to mind (perceptions; issues concerns/uncertainty; likes/dislikes), as well as their active decision

process in navigating the application while executing the task. The following instructions were provided

to participants: "Your daily target calorie limit is 2500; you just consumed a bowl of oatmeal, and you

opened the app to log the bowl of oatmeal." At this time, the usability was initiated as the facilitator

introduced the first screen (i.e., home screen). Upon completing the task, participants were asked to

reflect on their experience, and then each of the individual components (each containing engagement

strategies) were assessed individually for acceptability, relatability, and perceived

usefulness/effectiveness. Regarding problems/uncertainty experienced (as stated by participant) or

observed (as noted by facilitator) during the exercise, participants were asked to elaborate or provide

clarification on these flagged issues. Next, participants were asked about how their experience (in

relation to each of the components) could be improved.

3.2.3   Qualitative analysis

Overarching themes were identified across interview notes and transcriptions, and an affinity diagram

(Hartson and Pyla, 2012) was constructed. Each participant's data were organized into individual tables

based on the overarching themes identified. Each participant's data were then color coded (i.e., unique

color for each participant) and transferred to a master table (i.e., all participant data organized in one

table). Subthemes were then identified, and data were clustered accordingly (see *Appendix I* for

examples).

4.   Study results

4.1 Personalized feedback

Participants expressed a unifying desire for personalized feedback to be presented in a manner that was straightforward – quick and easy to digest – and required minimal cognitive interpretation or reflection. Most participants claimed that this could be achieved symbolically (i.e., with little to no text). P6 described how this was effectively achieved in his Fitbit app. At the end of the day, P6 likes to look back at the "star symbols" that represent goals accomplished that day. And when completing the daily goals a brief animation ensues, "When you hit all of [your goals], like this whole thing turns green, which is I think visually like kind of appealing to be like I hit all my goals today. Awesome." P2 related, "At the end of the day, I just want to look back and be happy at like what I see." And, P1 explicitly stated that she was not interested in seeing how many calories she had that day but rather "something to signify how healthy you are that day."

In the context of *e*wrapper, participants acknowledged that their progress could be effectively communicated symbolically through the growth of ostrich feathers. In addition, there was interest among a few participants to have some level of control over how their progress was presented- in personalized ways (i.e., of their choosing), which could increase user autonomy. Specifically, a few participants imagined alternative ways that progress or goal attainment could be represented. For example, unlocking or earning accessories that could be used to customize their ostrich. Accessorizing their ostrich could serve as a visual reminder of their progress. Moreover, some participants expressed interest in having their avatar evolve over time; or when crossing certain progress thresholds, having the option to switch to a different avatar. P5 further imagined this possibility as raising a zoo, which could foster long-term engagement.

An interesting distinction between low and high commitment participants was noted regarding the desire and usefulness of having an avatar. Specifically, participants that reported high commitment and engagement with past or current health apps were less keen on the idea of an avatar representing their progress. Rather, their preference was to have data visualizations and progress charts on the home screen, in place of the ostrich avatar. Contrarily, participants that reported lower levels of commitment and engagement with past health apps (i.e., used for a brief time and then abandoned), expressed more interest in having the ostrich avatar on the home screen, representing their performance/progress.

The preference of most participants was to receive feedback messages regarding their progress on a weekly and monthly basis, along with occasional feedback directly following self-monitoring (e.g., progress towards or achievement of daily goal; personal record streaks for consecutive loggings). The participants that reported high levels of commitment and engagement in current health apps, expressed interest in receiving more granular data (e.g., data on nutritional breakdown of food consumed), as well as insights into more general, overarching trends in their progress and eating behaviors. Regardless of the type of feedback, it was important to participants that the messaging be personalized and tailored to their progress and goals.

4.2 Reminders

Most participants spoke favorably about reminders, particularly the participants that had prior experience with self-monitoring applications. There were two notable aspects of reminders that participants communicated strong preferences about: 1) timing of receiving reminders; and the 2) content of reminders.

- *Timing of reminders*. The participants that welcomed reminders emphasized the importance of receiving the reminders either prior to or within (no more than) one hour of an eating episode.

Participants with prior experience using self-monitoring apps for calorie tracking claimed that if having forgotten to self-monitor, the motivation to do so decreased with time and their ability to accurately recall what all they consumed, and portion sizes became increasingly problematic. A few participants reported that if they could not remember everything they consumed during a meal or could not recall certain portion sizes, they would tend to not log anything from that meal. Considering the importance of reminders coupled with the complexities of reliably predicting or detecting eating episodes, P2 and P4 suggested that a "snooze" reminder option could be useful. That is, if users were to receive a reminder at an inconvenient or irrelevant time, they could choose to delay or snooze the reminder for a later time that day.

- *Content of reminders*. Two prominent themes emerged regarding the content of the reminders. First, there was a general consensus that variation of message content was preferred to static messages. P5 related that she had habituated to static messages sent by some of the apps she uses: "When it's varied…I pay attention to it…why do I have to read it if it's the exact same every single time…if it's different I'll click on it… 'Would you rather sit on a warm toilet seat or a cold toilet seat?' Like I'll click on that if it's interesting to me cause it's changing." Several of the participants claimed that reminders that highlight the need for a time-sensitive action could be highly motivating, such as receiving reminders to self-monitor to maintain a streak (e.g., consecutive daily goals attained). P2 would find it motivating if the messaging was personalized and occasionally reminded her of the goals she set for herself. The second theme involved the tone of the messages. Participants prefer the tone of reminder messages to be encouraging in nature (gentle nudges); whereas more directive and aggressive messages were described as being far less motivating. In fact, some reported that aggressive reminders actually had an adverse effect on participation. That is, aggressive messages would cause some participants to

ignore the notification or react with defiance and purposefully abstain from partaking in the

called action all together.

4.3 Rewards

Of the possible rewards participants can earn, it is no surprise that monetary incentives were most

desirable. As for the other content types, the vast majority of participant preferences were largely

influenced by the types of content that were not readily available or lacking through their regular

channels of content consumption (e.g., Instagram). Life hacks and fun facts were the content types that

attracted the most interest across participants; and when asked to explain their preference choices,

participants claimed that these types of content genuinely interested them and were largely missing or

lacking in their day-to-day media consumption. This is a significant finding worth reiterating: Participants

were asked about their preferences in content types and responded, *not with their actual preferences*;

but instead considered the content types they regularly consumed and responded with preferences

based on what was missing or lacking from their regular media consumption.

The remaining two types of content, humor and inspirational quotes, could also be desirable (though

inspirational quotes significantly less so); however, emphasis was placed on the need for tailoring across

content types – and this need was particularly pronounced in regard to sense of humor and what

individuals found inspiring. Relatedly, it is interesting to note that during the "think aloud" usability

exercise most participants voiced their assumption that rating the content would influence the selection

of subsequent content (i.e., content would adapt and be tailored to individual preferences over time).

This assumption could in part be attributed to the expected curation of content on social media

platforms based on user rating/usage patterns.

4.4 Punishment

Several of the participants were curious about whether there would be any penalty for exceeding the

daily calorie limit. Interestingly, these participants expressed curiosity about punishment at the same

juncture in the "think-aloud" exercise – when the calorie ring visualization was displayed. Another

logical juncture for inquiring about punishment would have been at the beginning of the exercise when

participants were told of their daily calorie limit goal; however, in each case, it was the presentation of

the calorie ring that triggered inquiry. This serves as a testament to the significance and influence of

visual narratives (i.e., the calorie ring) on goal salience. Participants were asked what they could imagine

occurring as a result of exceeding the calorie limit. P2 suggested that the calorie ring could transition

from blue to red. P5 imagined that the consequence be associated with the reward system; specifically,

that it would be more difficult to earn a reward. P3 claimed that a punishment mechanism would be

motivating only if she was committed to the app, "Like if it was just something I'm doing sporadically

and [the ostrich] lost his feathers, I probably would just get demoralized. But if it was something I'm

actually committed to, like I think that would help."

4.5 Social features

Participants, by and large, reported that social accountability, including in the context of teams, had the

potential of playing a significant role in their use of and motivation to use the app. However,

participants identified certain conditions that would need to be considered prior to their endorsement

or use of social features. First, in order for social accountability to be effective, participants emphasized

the need for a strong common thread that would link them with their teammates; and preferably,

participants would personally know their teammates. It was made apparent that if teammates were

completely anonymous the impression management aspect of accountability would be lost and there

would be no existing "real world" consequences for underperforming or not engaging. P1 mentioned

that the anonymity of teammates could work if there was some known shared identity. For example, P1

explained that she was a Zumba instructor and if she knew that her teammates were also Zumba

instructors this could serve as a strong enough common thread or link to hold her accountable and keep

her motivated to engage in the application. Another example of a strong common thread to facilitate

social accountability was sharing a common goal with their teammates. To make this more salient, P5

suggested having team-based rewards. She provided the example of having a special egg that

participants would work together – by achieving their individual goals – to achieve the group goal of

hatching the special egg.

There were a couple of participants that had no interest in social features or the social exchange of

progress within the app. P3 simply stated that she was not a competitive person and therefore would

not find social accountability motivating. P6 claimed that motivation and commitment were not issues

for him, and social involvement would not have an influence on his progress or goal attainment; thus, he

would not use social features. However, later in the interview P6 slightly retracted by claiming that he

would consider using social features if his level of commitment and progress could motivate or inspire

others.

5.   Discussion

5.1 Considerations for context-tailored feedback

Participants reported preferring progress/performance feedback that could be interpreted quickly and

with minimal cognitive effort. This suggestion should be strongly considered in the context of *e*wrapper,

particularly for the feedback messaging directly following self-monitoring where cognitive resources will

likely be limited (i.e., given the high cognitive demand of manually inputting dietary intake). Moreover,

studies have demonstrated that simple visual feedback can actually be effectively processed subliminally

(i.e., requiring no conscious/deliberate effort) and have an effect on subsequent behavior and decision-making (Ham, 2009). This perhaps suggests that simple visual feedback could potentially have an effect on users regardless of whether they were consciously receptive to the feedback. *What* effect and the *duration* of the effect remains unclear and warrants further investigation.

Design implication: The changing cognitive state (i.e., availability/receptivity) of users needs to be considered and feedback should be tailored accordingly. Inferring users' cognitive state is, in most cases, not (fully) possible; however, there are instances in which users' cognitive state can be better predicted (e.g., following the manual entry of a meal users likely have depleted cognitive resources). In such cases, it is important that feedback is tailored in a manner that users would (presumably) be most inclined/able to process. There is literature that substantiates this implication. The state of *cognitive receptivity* – defined as a "person's transient tendency to receive, process, and use the support provided" is a core consideration in the delivery of just-in-time adaptive interventions (Nahum Shani et al., 2015).

5.2 Time considerations for reminders

Participants with experience using self-monitoring apps to track dietary intake all reported trying to make a point of self-monitoring either before or very soon after consumption. Delayed self-monitoring (e.g., recording all consumption at the end of the day) was often problematic given the challenges of recalling what was consumed and the associated portion sizes of what was consumed. To this end, most participants acknowledged the benefits of receiving reminders; the timing of which was emphasized as critical. A couple of participants suggested implementing a "snooze" reminder feature which would enable users to delay a reminder received at an irrelevant/inconvenient time. Such a feature should be strongly considered in *e*wrapper as it would not only serve as an important facilitator for user engagement, but over time could adapt to individual user trends and time preferences – optimizing

delivery time points – which is the end goal of *e*wrapper: maximizing the potency of each individual

engagement strategy. Moreover, implemented effectively, this feature could eliminate the need for

"extra" (i.e., seemingly avoidable) UI to accommodate user control of reminder settings.

5.3 Preference for variation in content of reminders

Participants in favor of receiving reminders to self-monitor, by and large, would prefer the reminder

message content to vary (unpredictable content) rather than remain static (predictable/repeated

content). The theory of cost-benefit analysis (Boardman et al., 2017) could provide some insight into this

preference. First, it is important to consider each of the costs associated with opening the app and

manually inputting data. If we breakdown the costs in such a way, we can more critically examine the

weights of these costs and assess whether the necessary counterweights (i.e., the benefits) are in place

to offset the associated costs. Moreover, it is important to consider between-person heterogeneity in

relation to the perceived weights of these costs; and the role motivation and commitment play in

mediating the weights of these costs (i.e., the less motivated/committed the user, the greater the

perceived weight of the cost, and vice versa). Thus, users that evidence low-commitment may require

additional (or more potent) engagement strategies to increase the perceived benefit, and in turn

facilitate the behavior or interaction. Therefore, adding variation to the reminder messages and

including some incentive, could serve as the ounce of benefit needed to tip the scale and motivate some

less committed participants to engage.

Design implication: Each effort cost required of users within interventions should be counterbalanced

with user perceived benefits. If the effort costs outweigh the perceived benefits, users are at an

increased risk of abandoning the intervention (Shih et al., 2015). One suggested way to counterbalance

efforts costs is to facilitate "periodic reflection to help shift people's perceptions about the value that

they receive from the system relative to the effort required to use it" (Gulotta et al., 2016). Ambient or

glanceable displays (like *ewrapper)*, for example, have been shown to foster such reflection (Colsolvo et al., 2008).

5.4 Rewards to satisfy real-world needs/desires

When asked about preferences regarding reward content types, some of the participants first considered the types of content that they regularly consumed via social media and based their reward preferences on what was missing or lacking from their regular consumption. This suggests that users would rather supplement their current consumption with alternative engaging content than add more of the same content to their regular consumption. Moreover, this also suggests that there is a thirst or "room in their stomach" for engaging media content beyond their current intake.

Design implication: Identifying content that is engaging and not readily available to target demographics has the potential of being a worthy incentive to bolster engagement. Moreover, unlike most monetary incentives this form of incentive can be feasibly (and cost-effectively) implemented in the wild.

5.5 Preference for extrinsic vs. intrinsic motivators tied to level of commitment

It was evident that participants who reported low-commitment in prior use of mobile applications to self-monitor or track a behavior expressed more interest in the extrinsic motivation strategies than high-commitment participants. In particular, low-commitment participants preferred having the ostrich on the app home screen and expressed interest in earning accessories to decorate the ostrich to reflect progress (extrinsic motivator); whereas, high-commitment participants preferred having data visualizations on the app home screen and expressed interest in receiving insights into trends in their progress and eating behaviors (intrinsic motivator).

Design implication: The display and delivery performance/progress feedback needs to be tailored to current needs and preferences of individual users, and users should have the ability to modify the display and delivery at any time. In the context of ewrapper, users should have ongoing control over how their feedback is provided/represented (e.g., symbolically via the ostrich (Figure 1); directly via a data visualization (Figure 6); or perhaps a combination of both). A major shortcoming of existing mHealth interventions is their tendency to employ a "one size fits all" approach where all users are exposed to the same content without the option of personalization (Fleming et al., 2016).

In order to facilitate long-term engagement in low-commitment users, it is imperative to kindle and increase intrinsic motivation (Rapp, 2007), as extrinsically motivating strategies alone have a tendency to only be effective in the short-term and can stifle the possibility of any meaningful and enduring behavior change (Ryan and Deci, 2000; Benabou and Tirole, 2003). According to self-determination theory (Deci and Ryan, 1985) there are three intrinsic psychological needs that need to be met in order to foster intrinsic motivation: 1) *Competence:* perceived attainment of desired results through self-directed action*;* 2) *Autonomy:* ability to act freely, without external controls, in self-directed action or expression; and 3) *Social relatedness:* perceived belongingness, meaningfulness, or responsibility within a group setting. "*Don't ask how you can motivate other people. That's the wrong way to think about it. Instead ask how can you* <u>*create the conditions*</u> *in which other people will motivate themselves. And the answer quite simply is autonomy support*" (Deci, 2012). Building on this sentiment, to achieve intrinsic motivation, Zicherman (2011) suggested the need for adaptive extrinsic motivators that could evolve into intrinsic motivators over time. Though there are components built into *e*wrapper that aim to address the intrinsic psychological needs of users (e.g., *competence*: point system, unlocking rewards, feather growth; *autonomy*: choosing team; *social relatedness*: team-based goals, exchange of rewards), these components need to be revisited in light of the interview findings which unearthed ways to fine-tune or further cultivate the intrinsic motivation strategies. For example, increasing social relatedness by

making the reference group (i.e., teams) more salient by highlighting a common thread among "teammates". Another example would be to increase sense of autonomy by giving users the ability to *customize* their avatar with *earned* accessories, which could also increase users' sense of competence as the earned accessories would reflect progress/achievement. In both of these examples, we are taking inherently extrinsically motivating strategies and building in intrinsically motivating features, which could help increase long-term engagement.

Design implication: Consider ways to integrate intrinsically motivating strategies with extrinsically motivating strategies to facilitate long-term engagement. Our study results demonstrated heterogeneity in perceived receptivity to intrinsic and extrinsic motivators between low versus high commitment participants (i.e., low-commitment participants were more receptive to extrinsic motivators and high-commitment participants were more receptive to intrinsic motivators). To increase and sustain engagement among low-commitment users, it is imperative to find ways of cultivating intrinsic motivation. Thus, by integrating extrinsic motivators (what low-commitment users are more drawn to) with intrinsic motivating strategies the effects on engagement could be enhanced or sustained.

6.   Limitations

There were several limitations worth noting regarding the user study. First, given the limited sample size and demographic characteristics of study participants, the aforementioned findings cannot be generalized. Thus, a larger and more rigorous user study is warranted to further investigate these findings and to confirm and/or build on the related design implications. Second, the data collected was based on self-report and may not be representative of users' actual beliefs or opinions.

7.   Future work

If ewrapper demonstrates promising results it could have a significant public health impact; and not only in the context of self-monitoring dietary intake — ewrapper can be integrated with virtually any mHealth application to promote engagement in a variety of health behaviors. The overarching goal of *e*wrapper, across contexts, is to determine how the engagement strategies – individually and dynamically (i.e., working together or in sequence) — can be optimized for the individual user and under what conditions. The integration and evaluation of *e*wrapper with the self-monitoring dietary intake application will be a major building block towards developing a firm evidence base to support how this innovative intervention can be used effectively in the wild, and across various contexts.

8.   Conclusion

In summary, there exists great promise in digital technologies to address the limitations of and transform traditional health care service delivery systems. mHealth in particular, has effectively increased health behavior change in a wide range of both primary and secondary prevention treatments and modalities. To address the alarmingly high rates of attrition, its antecedents need to be better understood. Moreover, there needs to be a universal (i.e., across disciplines; or at the very least within the HCI community) conceptualization/definition of engagement, as well as a standardized set of guidelines (best practices) for measuring engagement (including for both objective and subjective methods and approaches). Next, it is critical that we increase our understanding of the effects individual engagement strategies have in a mobile setting (contextual, and within- and between-person heterogeneity factors need to be considered in this evaluation). Once the isolated effect(s) of individual engagement strategies is better understood, we can then develop more informed and strategic orchestrations of engagement strategies and develop new or revise existing theoretical frameworks to more effectively assess the integration/coupling and/or sequencing effects of the strategies within

adaptive and dynamic models/systems. The end goal is to optimize the operationalization of

engagement strategies, independently (i.e., individual strategies) as well as dynamically (i.e.,

integrating/sequencing strategies), and at an individual user level. Finally, it is imperative that we never

lose sight of the end-user. By increasing our understanding of the needs and preferences of users, the

more tailored and accommodating digital technologies can be, which will inevitably increase adoption

and use of these technologies – ultimately creating a feedback loop (i.e., as use increases as will the

ability to more effectively tailor the technologies). In other words, as digital technologies become more

aware of us as individuals – our unique behaviors, habits, curiosities, social roles – the less aware we will

be of technology. Thus, "*the best (engagement) is yet to come."*

9.   References

Alahäivälä, T., & Oinas-Kukkonen, H. (2016). Understanding persuasion contexts in health gamification:

A systematic analysis of gamified health behavior change support systems

literature. *International journal of medical informatics*, *96*, 62-70.

Andrewchen.co. New data shows losing 80% of mobile users is normal, and why the best apps do better

2016 URL: http://andrewchen.co/new-data-shows-why-losing-80of-your-mobile-users-is-normal-and-that-the-best-apps-do-much-better/ [WebCite Cache]

Asimakopoulos, S., Asimakopoulos, G., & Spillers, F. (2017, March). Motivation and user engagement in

fitness tracking: Heuristics for mobile healthcare wearables. In *Informatics* (Vol. 4, No. 1, p. 5).

Multidisciplinary Digital Publishing Institute.

Attfield, S., Kazai, G., Lalmas, M., & Piwowarski, B. (2011, February). Towards a science of user

engagement (position paper). In *WSDM workshop on user modelling for Web applications* (pp. 9-

12).

Baker, T. B., Gustafson, D. H., & Shah, D. (2014). How can research keep up with eHealth? Ten strategies

for increasing the timeliness and usefulness of eHealth research. *Journal of medical Internet*

research, *16*(2).

Benabou, R., & Tirole, J. (2003). Intrinsic and extrinsic motivation. The review of economic studies, 70(3),

489-520.

Blanson Henkemans, O. A., Rogers, W. A., & Dumay, A. M. C. (2011). Personal characteristics and the law

of attrition in randomized controlled trials of eHealth services for self-care.

Bouvier P, Lavoue E, Sehaba K. Defining engagement and characterizing engaged-behaviors in digital

gaming. Simulation Gaming. 2014; 45 (4-5): 491–507.

Brown, S. L. (2003). An altruistic reanalysis of the social support hypothesis: The health benefits of

giving.

Carver, C. S., & Scheier, M. F. (1982). Control theory: A useful conceptual framework for personality–

social, clinical, and health psychology. *Psychological bulletin*, *92*(1), 111.

Carver, C. S., & Scheier, M. F. (1981). The self-attention-induced feedback loop and social

facilitation. *Journal of Experimental Social Psychology*, *17*(6), 545-568.

Christensen, H., & Mackinnon, A. (2006). The law of attrition revisited. *Journal of medical Internet

research*, *8*(3).

Cole-Lewis, H., & Kershaw, T. (2010). Text messaging as a tool for behaviour change in disease

prevention and management. *Epidemiologic Reviews*, *32*(1), 56–69.

Cialdini, R. B. (2001). Harnessing the science of persuasion. *Harvard business review*, *79*(9), 72-81.

Clawson, J., Pater, J. A., Miller, A. D., Mynatt, E. D., & Mamykina, L. (2015, September). No longer

wearing: investigating the abandonment of personal health-tracking technologies on craigslist.

In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous

Computing* (pp. 647-658). ACM.

Cole-Lewis, H., & Kershaw, T. (2010). Text messaging as a tool for behaviour change in disease

prevention and management. *Epidemiologic Reviews*, *32*(1), 56–69.

Consolvo, S., McDonald, D. W., Toscos, T., Chen, M. Y., Froehlich, J., Harrison, B., ... & Smith, I. (2008,

April). Activity sensing in the wild: a field trial of ubifit garden. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 1797-1806). ACM.

Cordeiro, F., Epstein, D. A., Thomaz, E., Bales, E., Jagannathan, A. K., Abowd, G. D., & Fogarty, J. (2015, April). Barriers and negative nudges: Exploring challenges in food journaling. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (pp. 1159-1162). ACM.

Csikszentmihalyi, M. (1990). The domain of creativity.

Deci, E.L. (2012, August). Promoting Motivation, Health, and Excellence. Retrieved from

https://youtu.be/VGrcets0E6I

Deci, E. L., & Ryan, R. M. (2012). Motivation, personality, and development within embedded social contexts: An overview of self-determination theory. *The Oxford handbook of human motivation*, 85-107.

Deci, E. L., & Ryan, R. M. (1985). The general causality orientations scale: Self-determination in personality. *Journal of research in personality*, *19*(2), 109-134.

Dekker, R. L., Peden, A. R., Lennie, T. A., Schooler, M. P., & Moser, D. K. (2009). Living with depressive symptoms: patients with heart failure. *American Journal of Critical Care*, *18*(4), 310-318.

Deterding, S., Sicart, M., Nacke, L., O'Hara, K., & Di4xon, D. (2011, May). Gamification. using game-design elements in non-gaming contexts. In *CHI'11 extended abstracts on human factors in computing systems* (pp. 2425-2428). ACM.

Doherty, K., & Doherty, G. (2018). Engagement in HCI: Conception, Theory and Measurement. *ACM Computing Surveys (CSUR)*, *51*(5), 99.

eMarketer. (n.d.). Number of smartphone users in the United States from 2010 to 2022 (in millions)

Epstein, D. A., Caraway, M., Johnston, C., Ping, A., Fogarty, J., & Munson, S. A. (2016, May). Beyond abandonment to next steps: understanding and designing for life after personal informatics tool use. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (pp.

1109-1113). ACM.

Ericsson, K. A., & Simon, H. A. (1998). How to study thinking in everyday life: Contrasting think-aloud

protocols with descriptions and explanations of thinking. *Mind, Culture, and Activity*, *5*(3), 178-

186.

Eysenbach, G. (2005). The law of attrition. *Journal of medical Internet research*, *7*(1).

Farago P. App Engagement: The Matrix Reloaded. Available at:

http://flurrymobile.tumblr.com/post/113379517625/app-engagement-the-matrix-reloaded

Ferster, C. B., & Skinner, B. F. (1957). Schedules of reinforcement.

Fleming, T. M., De Beurs, D., Khazaal, Y., Gaggioli, A., Riva, G., Botella, C., ... & Merry, S. (2016).

Maximizing the impact of e-therapy and serious gaming: time for a paradigm shift. *Frontiers in*

psychiatry, *7*, 65.

Free, C., Phillips, G., Galli, L., Watson, L., Felix, L., Edwards, P., ... & Haines, A. (2013). The effectiveness of

mobile-health technology-based health behaviour change or disease management interventions

for health care consumers: a systematic review. *PLoS medicine*, *10*(1), e1001362.

Goldstein, N. J., Cialdini, R. B., & Griskevicius, V. (2008). A room with a viewpoint: Using social norms to

motivate environmental conservation in hotels. *Journal of consumer Research*, *35*(3), 472-482.

Gouldner, A. W. (1960). The norm of reciprocity: A preliminary statement. *American sociological review*,

161-178.

Gouveia, R., Karapanos, E., & Hassenzahl, M. (2015, September). How do we engage with activity

trackers?: a longitudinal study of Habito. In *Proceedings of the 2015 ACM International Joint*

Conference on Pervasive and Ubiquitous Computing (pp. 1305-1316). ACM.

Grenard, J. L., Stacy, A. W., Shiffman, S., Baraldi, A. N., MacKinnon, D. P., Lockhart, G., ... & Ames, S. L.

(2013). Sweetened drink and snacking cues in adolescents. A study using ecological momentary

assessment. *Appetite*, *67*, 61-73.

Grist, R., Porter, J., & Stallard, P. (2017). Mental health mobile apps for preadolescents and adolescents: a systematic review. *Journal of medical internet research*, *19*(5), e176.

Gulotta, R., Forlizzi, J., Yang, R., & Newman, M. W. (2016, June). Fostering engagement with personal informatics systems. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems* (pp. 286-300). ACM.

Ham, J., Midden, C., & Beute, F. (2009, April). Can ambient persuasive technology persuade unconsciously?: using subliminal feedback to influence energy consumption ratings of household appliances. In *Proceedings of the 4th International Conference on Persuasive Technology* (p. 29). ACM.

Hamari, J., Koivisto, J., & Sarsa, H. (2014, January). Does Gamification Work? A Literature Review of Empirical Studies on Gamification. In *HICSS* (Vol. 14, No. 2014, pp. 3025-3034).

Hartson, R., & Pyla, P. S. (2012). *The UX Book: Process and guidelines for ensuring a quality user experience*. Elsevier.

Hekler, E. B., Klasnja, P., Froehlich, J. E., & Buman, M. P. (2013, April). Mind the theoretical gap: interpreting, using, and developing behavioral theory in HCI research. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 3307-3316). ACM.

Hekler, E. B., Michie, S., Pavel, M., Rivera, D. E., Collins, L. M., Jimison, H. B., ... & Spruijt-Metz, D. (2016). Advancing models and theories for digital behavior change interventions. *American journal of preventive medicine*, *51*(5), 825-832.

Hull, C. L. (1932). The goal-gradient hypothesis and maze learning. *Psychological Review*, *39*(1), 25.

Hurling, R., Catt, M., De Boni, M., Fairley, B. W., Hurst, T., Murray, P., ... & Sodhi, J. S. (2007). Using internet and mobile phone technology to deliver an automated physical activity program: randomized controlled trial. *Journal of medical Internet research*, *9*(2).

In *Statista - The Statistics Portal*. Retrieved from

https://www.statista.com/statistics/201182/forecast-of-smartphone-users-in-the-us/

Johnson, D., Deterding, S., Kuhn, K. A., Staneva, A., Stoyanov, S., & Hides, L. (2016). Gamification for

 health and wellbeing: A systematic review of the literature. *Internet interventions*, *6*, 89-106.

Kitsiou, S., Paré, G., Jaana, M., & Gerber, B. (2017). Effectiveness of mHealth interventions for patients

 with diabetes: An overview of systematic reviews. *PloS one*, *12*(3), e0173160.

Kivetz, R., Urminsky, O., & Zheng, Y. (2006). The goal-gradient hypothesis resurrected: Purchase

 acceleration, illusionary goal progress, and customer retention. *Journal of Marketing*

 Research, *43*(1), 39-58.

Kohl, L. F., Crutzen, R., & de Vries, N. K. (2013). Online prevention aimed at lifestyle behaviors: a

 systematic review of reviews. *Journal of medical Internet research*, *15*(7).

Krebs, P., & Duncan, D. T. (2015). Health App Use Among US Mobile Phone Owners: A National Survey.

 JMIR mHealth and uHealth, *3*(4), e101.

Kumar, S., Nilsen, W. J., Abernethy, A., Atienza, A., Patrick, K., Pavel, M., ... & Hedeker, D. (2013). Mobile

 health technology evaluation: the mHealth evidence workshop. *American journal of preventive*

 medicine, *45*(2), 228-236.

Kumar, S., Nilsen, W., Pavel, M., & Srivastava, M. (2013). Mobile health: Revolutionizing healthcare

 through transdisciplinary research. *Computer*, *46*(1), 28-35.

Kukafka, R., Johnson, S. B., Linfante, A., & Allegrante, J. P. (2003). Grounding a new information

 technology implementation framework in behavioral science: a systematic analysis of the

 literature on IT use. *Journal of biomedical informatics*, *36*(3), 218-227.

Lazar, A., Koehler, C., Tanenbaum, J., & Nguyen, D. H. (2015, September). Why we use and abandon

 smart devices. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and*

 Ubiquitous Computing (pp. 635-646). ACM.

Ledger, D., & McCaffrey, D. (2016). How the science of human behavior change offers the secret to long-

term engagement. 2014. *Retrieved online from http://endeavourpartners. net/white-papers*.

Li, I., Dey, A., & Forlizzi, J. (2010, April). A stage-based model of personal informatics systems. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 557-566).

Locke, E. A., & Latham, G. P. (1990). *A theory of goal setting & task performance*. Prentice-Hall, Inc.

Makovsky Health. The Digitally Empowered Patient. Available at: http://www.makovsky.com/insights/blogs/m-k-health/44-insights/blogs/m-k-health/732- the-digitally-empowered-patient.

Mekler, E. D., Brühlmann, F., Tuch, A. N., & Opwis, K. (2015). Towards understanding the effects of individual gamification elements on intrinsic motivation and performance. *Computers in Human Behavior*, *71*, 525-534.

Milliken, F. J. (1987). Three types of perceived uncertainty about the environment: State, effect, and response uncertainty. *Academy of Management review*, *12*(1), 133-143.

Nacke, L. E., & Deterding, C. S. (2017). The maturing of gamification research. *Computers in Human Behaviour*, 450-454.

Nahum-Shani, I., Hekler, E. B., & Spruijt-Metz, D. (2015). Building health behavior models to guide the development of just-in-time adaptive interventions: A pragmatic framework. *Health Psychology*, *34*(S), 1209.

O'Brien, H. L., & Toms, E. G. (2008). What is user engagement? A conceptual framework for defining user engagement with technology. *Journal of the Association for Information Science and Technology*, *59*(6), 938-955.

Ostojic, V., Cvoriscec, B., Ostojic, S. B., Reznikoff, D., Stipic-Markovic, A., & Tudjman, Z. (2005). Improving asthma control through telemedicine: a study of short-message service. *Telemedicine Journal & E-Health*, *11*(1), 28-35.

Perski, O., Blandford, A., West, R., & Michie, S. (2017). Conceptualising engagement with digital behaviour change interventions: a systematic review using principles from critical interpretive

synthesis. *Translational behavioral medicine*, 1-14.

Peters, C., Castellano, G., & de Freitas, S. (2009, November). An exploration of user engagement in HCI.
In *Proceedings of the International Workshop on Affective-Aware Virtual Agents and Social Robots* (p. 9). ACM.

Rabbi, M., Philyaw-Kotov, M., Lee, J., Mansour, A., Dent, L., Wang, X., ... & Walton, M. (2017,
September). SARA: a mobile app to engage users in health data collection. In *Proceedings of the 2017 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2017 ACM International Symposium on Wearable Computers* (pp. 781-789).

Rapp, A., Hopfgartner, F., Hamari, J., Linehan, C., & Cena, F. (2018). Strengthening gamification studies:
Current trends and future opportunities of gamification research.

Rapp, A. (2017). From games to gamification: A classification of rewards in World of Warcraft for the
design of gamified systems. *Simulation & Gaming*, *48*(3), 381-401.

Rooksby, J., Rost, M., Morrison, A., & Chalmers, M. (2014, April). Personal tracking as lived informatics.
In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 1163-1172). ACM.

Rosen, R. K., Ranney, M. L., & Boyer, E. W. (2015, January). Formative research for mHealth HIV
adherence: the iHAART app. In *System Sciences (HICSS), 2015 48th Hawaii International Conference on* (pp. 2778-2785). IEEE.

Ryan, C., Bergin, M., & Wells, J. S. (2018). Theoretical perspectives of adherence to web-based
interventions: a scoping review. *International journal of behavioral medicine*, *25*(1), 17-29.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new
directions. *Contemporary educational psychology*, *25*(1), 54-67.

Sailer, M., Hense, J. U., Mayr, S. K., & Mandl, H. (2017). How gamification motivates: An experimental
study of the effects of specific game design elements on psychological need

satisfaction. *Computers in Human Behavior*, *69*, 371-380.

Sarsam, S. M., & Al-Samarraie, H. (2018). A first look at the effectiveness of personality dimensions in

promoting users' satisfaction with the system. *SAGE Open*, *8*(2), 2158244018769125.

Seaborn, K., & Fels, D. I. (2015). Gamification in theory and action: A survey. *International Journal of*

human-computer studies, *74*, 14-31.

Schlosser, D. A., Campellone, T. R., Truong, B., Anguera, J. A., Vergani, S., Vinogradov, S., & Arean, P.

(2017). The feasibility, acceptability, and outcomes of PRIME-D: A novel mobile intervention

treatment for depression. *Depression and anxiety*, *34*(6), 546-554.

Shih, P. C., Han, K., Poole, E. S., Rosson, M. B., & Carroll, J. M. (2015). Use and adoption challenges of

wearable activity trackers. *IConference 2015 Proceedings*.

Steichen, B., Carenini, G., & Conati, C. (2013, March). User-adaptive information visualization: using eye

gaze data to infer visualization tasks and user cognitive abilities. In *Proceedings of the 2013*

international conference on Intelligent user interfaces (pp. 317-328). ACM.

Turner-McGrievy, G. M., Beets, M. W., Moore, J. B., Kaczynski, A. T., Barr-Anderson, D. J., & Tate, D. F.

(2013). Comparison of traditional versus mobile app self-monitoring of physical activity and

dietary intake among overweight adults participating in an mHealth weight loss program.

Journal of the American Medical Informatics Association, *20*(3), 513-518.

Tversky, A., & Kahneman, D. (1991). Loss aversion in riskless choice: A reference-dependent model. *The*

quarterly journal of economics, *106*(4), 1039-1061.

Volpp, K. G., John, L. K., Troxel, A. B., Norton, L., Fassbender, J., & Loewenstein, G. (2008). Financial

incentive–based approaches for weight loss: a randomized trial. *Jama*, *300* (22), 2631-2637.

Wagner III, B., Liu, E., Shaw, S. D., Iakovlev, G., Zhou, L., Harrington, C., ... & Spring, B. (2017, September).

*e*wrapper: operationalizing engagement strategies in mHealth. In *Proceedings of the 2017 ACM*

International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the

2017 ACM International Symposium on Wearable Computers (pp. 790-798). ACM.

Wilson, T. D., Centerbar, D. B., Kermer, D. A., & Gilbert, D. T. (2005). The pleasures of uncertainty:

prolonging positive moods in ways people do not anticipate. *Journal of personality and social*

psychology, *88*(1), 5.

Woolley, K., & Fishbach, A. (2017). Immediate rewards predict adherence to long-term goals. *Personality*

and Social Psychology Bulletin, *43*(2), 151-162.

Yardley, L., Spring, B. J., Riper, H., Morrison, L. G., Crane, D. H., Curtis, K., ... & Blandford, A. (2016).

Understanding and promoting effective engagement with digital behavior change interventions.

American journal of preventive medicine, *51*(5), 833-842.

Yeager, C. M., & Benight, C. C. (2018). If we build it, will they come? Issues of engagement with digital

health interventions for trauma recovery. *MHealth*, *4*.

Zichermann, G. (2011). Gamification - the new loyalty [Video]. Copenhagen: Gamification Co. Retrieved

from http://vimeo.com/25714530

10.   Appendix

COMPONENTS	Likes	Dislikes	Facilitators	Barriers	Desired changes/ improvements	OTHER
Logging	(01:10) "you have that associated a wristband that will collect data as I'm going about doing my business throughout the day." (01:25) has to be my responsibility to turn it on the tracker (07:44) if you use the scale, it'll automatically track your weight gain, which is very cool. (19:27) if it's not in [scanner], you can literally and request them to add it (22:03) it just be a one time thing where I manually plugin and then every time I had a food log I'll just click on that.	(06:33) food intake was also manual, so you have to literally go in there and like put in what kind of food you've taken (19:59) I don't manually put it in because it's such a hassle to have to go and be like, oh, this has this much fat. Oh this has this much like sugar.	(06:39) fitbit will calculate the calories, are percent fats and carbs, all that stuff for you (06:56) you click on this and the like a scanner will pop up and you can literally just scan barcodes from food and it will automatically put it in here. (07:11) for uh, water and weight gain. They have their own tools, so they have their own water bottle. (01:25) has to be my responsibility to turn it on the track (22:03) it just be a one time thing where I manually plugin and then every time I had a food log I'll just click on that.	(07:32) it's self-tracking water bottle] is kind of expensive (10:48) It's hard to like maintain these because you know, asleep like depending on like how much homework or like look how busy my week is. Like there's not much I can do (11:49) Food I've been able to do pretty well with only the summer when I know when everything you had like a straight schedule.	(05:52) Your current weight versus your optimal weight or what you want in your optimal weight and you that then?	(02:39) So it's like nice to use and it's like all on like one like screen General barrier: (08:55) it'd be really cool for them to have like more customizable stuff like changing the color right now it's like all white (12:23) over the summer I'm more disciplined in terms of going to the gym and those two work together. (38:45) I wish had a little bit more control on like the color scheme (47:47) I always take the longer route because of this app and this like wrist watch versus in the past I knew like I'll just go to the closest bathroom because it's more convenient general improvement: (49:45) have like an app that like adapts like the lifestyle of a Grad student or an Undergrad, but for someone like an adult who has like systematic life, it'd be much different (52:56) this app would kind of suck without the wrist watch because a lot of these, a lot of the data here is motivated by the watch ran the watch itself.

Overarching theme (individual) example: Above is P6's data related to "Logging" food/drink in his Fitbit app; organized by overarching themes

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PERSONALIZED FEEDBACK

FREQUENCY
J: That's one thing you can show like my weekly progress or my daily progress: end of day and week
J: *On frequency of updates:* I mean, it'd be cool if like, you know, after so many log ins, **like after a month if I stayed under my goal,** like little updates
S: Weekly reports (like Apple screen time notification); would like occasional feedback after logging
TT: Trends on weekly/monthly basis
MG: Per day and then like per week and per month

METHOD OF DELIVERY & CONTROL
J: *"What do you think about receiving feedback via push notification?"* Yeah, that would be fine cause If doing something and I don't have time to click into that. That notification would be cool.
S: Progress not in the form of a push notification. But would be after logging.
J: Would like the ability to control the time of day to receive feedback or notifications

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VISUAL FEEDBACK
MG: I think at the end of the day, I just want to like look back and like be happy at like what I see.
TT: Put like a star on the days you hit, which I think is really cool. Like visually, like you, like, you know, words are more informative. Like visually you see it and you're seeing like, oh, like I'm hitting my goals, I'm not hitting my goals.
S: I wouldn't want it to be like how many calories you ate that day, but like something that would signify like the overview of how like, well you did that day and then if you could see it like this, I think I would like that. I don't think I want the total calories but like something to signify like how healthy you are that day.

OTHER DATA DESIRED
TL: when I'm having the most calories so you could like kind of distributed more evenly; interested in seeing general categories of food that I've had: like how many times and x amount of time am I having this item? What's the most common time? What time of the month or when having this item most often. Link back and see what I was doing in my life at that time to kind of see if this is like maybe a process of stress or other influential factors in my life
S: I don't have the knowledge of understanding food broken down into groups (such as carbs) so wouldn't be useful to me
MG: would like it paired with other health data to be like physical activity; calorie to factor in (and also display) calories burned

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PUNISHMENT
MS: I think it depended how, like how set I was on my goal. Like if it was just something I'm doing sporadically and it lost his feathers, I probably would just get demoralized. But if it was something I'm actually committed to, like I think that would help. So I think it, it would just depend on like what the is like what the end goal is. Like what's the goal.
MG: Blue could turn to red when exceeding 2500 calories (or goal calorie amount)
TL: Egg would be harder to hatch

Sub-theme (sample) example: Above is a synthesis of participants' data related to "Personalized feedback" preferences; organized by sub-themes