8-6-2011

Electronic Food and Exercise Diaries: Knowledge Gaps and Future Research

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ABSTRACT

Electronic food and exercise diaries are increasingly popular, both on the Internet and mobile devices. These tools offer a potential low-cost solution to help control and manage weight in those who suffer from obesity, as well as reduce the strain of obesity on the Canadian healthcare system. The body of knowledge for electronic food and exercise diaries, however, is lacking as to their effectiveness and related issues. This paper presents several key issues pertaining to the use of these applications, as well as proposed research directions, in which theories integrated from different areas can address these gaps. These theories include those that address acceptance of technology, continuity of use, and ability to produce behavioral change. Preliminary research results indicate that the diaries are effective in weight reduction, but issues associated with initial adoption remain.

Keywords

E-food and exercise diary, obesity, usability, relapse prevention, technology acceptance.

INTRODUCTION

The prevalence of obesity in Canada is at such a level that it is commonly referred to as an "epidemic" (CBC, 2005; Thorpe, Florence, Howard and Joski, 2004). The number of obese children in Canada has tripled in recent years, and it is now being considered a critical health issue along with smoking (PHAC, 2006). Such a high prevalence of obesity is straining healthcare systems (Bhattacharya and Bundorf, 2009). In 2004, it was estimated that the cost of obesity to the Canadian healthcare system was $4.3 billion (Katzmarzyk and Janssen, 2004). Self-monitoring of conditions by individuals has been the source of success in weight control, as it is a necessary element for effective self-regulation (Baker and Kirschenbaum, 1993). Electronic food and exercise diaries (eFEDs), sometimes referred to as calorie counters, are tools that can be used to manage caloric intake and expenditure. These diaries are used to record calories both consumed from eating and expended by physical exercise, the daily net of which is not to exceed a personalized budget. These diaries facilitate the management of three effective weight loss strategies: calorie reduction, increased physical activity and behavioral modification.

The pervasiveness of the Internet and expanding use of smart phones have enabled new capabilities for eFEDs. This technology has several advantages over the pencil-and-paper method, such as the elimination of the need to perform repetitive calculations by hand, the convenient availability of calorie data, graphical displays of data, and the integration of supplementary tools, such as social networks and reminders (Kamal, Fels and Ho, 2010). This paper presents several key issues pertaining to the use of electronic food and exercise diaries. To this end, pertinent knowledge gaps associated with the use of eFEDs will be discussed. The discussion will further highlight several theoretical frameworks that can be used to address the identified knowledge gaps, as well as preliminary research plans and results.

BACKGROUND

eFEDs are characterized by the means which the three types of data - calories in, calories out, and weight - are collected, monitored and analyzed. Entry of calories consumed is typically facilitated by an extensive database of foods and exercise, as well as their related nutritional and caloric data. When users eat, they select the food and portion size from the database, and the calories consumed are automatically calculated. Similarly, when users perform physical activity, they select the type of activity and its duration, and the resulting calories are calculated. A graphical interface is updated in real time when food or exercise calories are calculated, so that users can compare their daily net calories to an individualized daily calorie budget. As well, when users enter their weight, a line graph is updated, which displays weight change over the period of use. eFEDs employ many different types of reports to facilitate monitoring of diet, such as weekly summaries and diet constitution. Supplementary features include integration with social networks and electronic reminders, if users have not logged. These diaries are available in the form of a website, and can frequently integrate with applications on mobile devices.

If one were to review the extant literature in the domain of eFEDs, one would find an emerging body of knowledge, with inconsistent conclusions with respect to their effectiveness (Neve, Morgan, Jones and Collins, 2010). Figure 1 (below) depicts the *eFED Evaluation Model*, informed by the knowledge gaps associated with the use of these diaries. They include, but may not be limited to, the continuity of use and treatment (utility), usability factors of the applications (usability), the effect of application features (features), acceptance and preference (adoption), and the resulting benefits of use (outcomes).

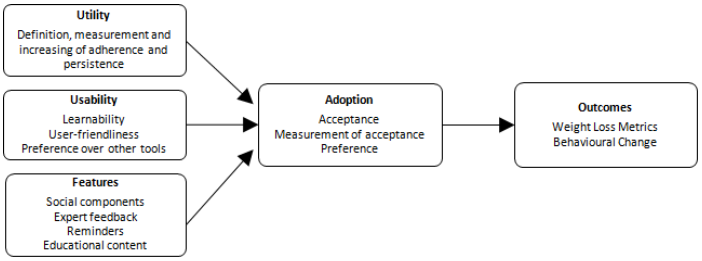

Figure 1: The eFED Evaluation Model, informed by knowledge gaps associated with electronic food and exercise diaries (eFEDs). Variables include the continuity of use and treatment (utility), usability factors of the applications (usability), the effect of application features (features), acceptance and preference (adoption), and the resulting benefits of use (outcomes).

Utility

The utility of the eFED should support the continuity of its use. *Continuity*, for the purpose of this paper, is a provisional term that will refer to issues surrounding the continued use of eFEDs, and will be used to collectively reference the concepts of adherence, persistence and attrition to both the eFED and the desired behavior. *Adherence*, which is also referred to as compliance, is defined as the degree to which the patient conforms to the recommendations of the treatment with respects to dosage, timing and frequency (Cramer, Roy, Burrell, Fairchild, Fuldeore, Ollendorf and Wong, 2008). Whereas adherence entails following an appropriate treatment regimen, *persistence* is the act of continuing the treatment for the prescribed duration. Both adherence and persistence are related directly to the effectiveness of the treatment (Inouye, Bogardus, Williams, Leo-Summers and Agostini, 2003). *Attrition*, which refers to the rate of participants who drop out of a study, has also been used (Carter-Edwards, Bastian, Schultz, Amamoo and Østbye, 2009; Vereecken, Covents, Haynie and Maes, 2009).

Exploring issues of adherence and persistence of treatments can generate knowledge that can contribute to increased effectiveness. Burke, Styn, Glanz, Ewing, Elci, Conroy, Sereika, Acharya, Music, Keating and Sevick (2009), in a randomized controlled trial involving a PDA-based eFED, hypothesized that barriers to healthy eating, self-efficacy, problem-solving skills, acceptance of technology and effects of life events can affect adherence to treatment. Mattila, Lappalainen, Pärkkä, Salminen and Korhonen (2010) analyzed the weekly pattern of weight loss in a 12-week study of using a wellness diary application on a mobile phone. The authors suggested that, due to the presence of a weekly pattern of weight loss, there may be "risk periods", where users may be at risk of non-adherence to treatment.

Several issues of measurement of adherence and persistence suggest the need for improved conceptual definitions of these variables. First, distinction may be drawn between adherence in use of the application, self-monitoring, and the treatment itself. For example, using obesity self-monitoring software, in and of itself, is not a treatment; rather it facilitates the processes associated with self-monitoring of food, exercise and the like. As well, the use of an electronic food diary may constitute only a portion of the amount of self-monitoring needed. For example, diabetics may need to monitor glucose levels, as well as food and exercise. Therefore, if adherence or persistence is operationalized as a specific volume usage metric, it is adherence and persistence to the application itself that is being measured, not to the treatment per se.

Second, conceptual definitions of adherence are inconsistently used (Cramer et al., 2008). Some studies that purport to measure adherence proceed to the operational definition without thoroughly defining the conceptual, for example (Burke, Swigart, Warziski Turk, Derro and Ewing, 2009; Marcus, Rosen, Davidson Ward, Halbower, Sterni, Lutz, Stading, Bolduc and Gordon, 2006). Furthermore, the lack of a conceptual definition may also result in confusion between issues of adherence and persistence. Fukuo, Yoshiuchi, Ohashi, Togashi, Sekine, Kikuchi, Sakamoto, Inada, Sato, Kadowaki and Akabayashi (2009) measure *both* adherence and compliance as separate variables. Lu, Pearson, Renker, Myerburg and Farino (2006) measure adherence with the same formula that Fukuo et al. (2009) used to measure compliance. Attrition was also used as a concept pertaining to the participants' quitting the research study before the end, and has not been sufficiently explored in previous research (Neve et al., 2010; Vereecken et al., 2009).

Third, the level of validity of using self-reported methods for the measurement of adherence is low. Self-reported adherence has performed inconsistently with objective indicators; therefore self-report methods may not be valid for assessing adherence (Beasley, Riley, Davis and Singh, 2008; Marcus et al., 2006). Adherence has been operationalized in several ways, such as comparing diary data to unannounced dietary recalls, attendance rate at treatment sessions, and by analyzing the timestamp of entries in the PDA (Burke, Styn, et al., 2009). Often, this compromises a proper accounting and cross-comparison of study findings and outcomes.

The fourth issue is the need to improve adherence and persistence with eFEDs. Carter-Edwards et al. (2009) reported on a community-wide weight loss program, in which 21.8% of participants finished. Beasley et al. (2008) compared the use of both a paper-based and PDA-based eFED, in which a medium level of adherence to monitoring (> 63% of all meals were logged) is sustained, and found that adherence to the diet towards the end of the month was low for both groups (< 15%).

Usability

As noted, eFEDs have advantages over paper-based diaries, including the availability of calorie data, enhanced reporting capabilities, as well as other benefits. With the increased number of capabilities available, usability engineering must be performed to ensure that the application meets the requirements and needs of novice, expert and casual users (Nielsen, 1993). *Usability* is defined using five concepts: learnability, efficiency of use, memorizability, errors and satisfaction. Learnability refers to the ease in which a novice user can use the system. Efficiency of use pertains to the speed in which an experienced user can perform a certain function. Memorizability of a system is important for users who need to remember how to use the system on a sporadic basis. Errors in a system should be as few as possible in number, and as non-catastrophic as appropriate. Subjective satisfaction with the system may be a more important usability factor when the user is not forced to use the system. The usability of an eFED is likely to have a positive effect on its usage. (Burke, Warziski, Starrett, Choo, Music, Sereika, Stark and Sevick, 2005) reported on two pilot studies that used PDA-based food diaries, which reported "good to excellent" (p. 289) levels of self-monitoring, along with a high degree of learnability for each application. In Vereecken et al. (2009) study, users rated an eFED significantly with respect to user-friendliness, attractiveness, having adequate instructions, clarity in information and ease in finding food items.

Features

Features that accompany eFEDs can contribute to increased adherence and persistence, or positive outcomes. In a review of web-based eFEDs, Neve et al. (2010) concluded that the presence of certain features contribute to positive weight change, but it is not known if any of these features are associated with improved adherence. Among the features identified are social components, expert feedback, reminders and educational content.

Carter-Edwards et al. (2009) reported on a weight-loss contest, which included both social and educational components. Participants had the option of entering the contest as a team, and there was no significant difference on weight loss between team and individual participants. Online educational resources were supplied to the intervention group, while the control group received printed literature. Although the group that received printed literature performed better, both groups reported significant weight loss. The use of reminders was suggested as a way to increase retention in future programs.

Neve et al. (2010) performed a systematic review for the purpose of determining the effectiveness of web-based interventions in achieving weight loss and maintenance. Social features included chat rooms, bulletin boards, and face-to-face meetings. Positive weight outcomes were associated with meeting attendance rates and amount of forum posts. The review reported that the effect of social features and reminders on adherence still lacks rigorous investigation. As well, the inclusion of educational material and expert counseling were found to be associated with increased weight loss.

Krukowski, Harvey-Berino, Ashikaga, Thomas and Micco (2008) attempted to determine the features of web-based weight management programs that result in the highest benefit for its users. In general, features that provide feedback, social support and motivation were related to weight loss. Specifically, features that delivered feedback (for example, charts, calculators) were important during treatment and social support (for example, chat) was important during maintenance.

Adoption

Both acceptance and preference of the eFED application and technology are two user-centric issues that can affect the adoption of an eFED. Acceptance is defined and operationalized by many models, two of the most popular and well-established being the Technology Acceptance Model (TAM; Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh, Morris, Davis and Davis, 2003). Both models rest on the premise that the perceived ease of use and usefulness of a technology, along with social norms and organizational facilitating factors, can predict the intent to use an application, and subsequently the actual use.

Studies that evaluate the acceptance of eFEDs are sporadic. Of these, studies that utilize highly conceptualized versions of acceptance are even more limited. Despite some valuable insights, Mattila et al. (2010) did not use a theoretical framework to measure acceptance. Burke, Styn et al. (2009) purported to assess acceptance, but instead utilized a scale based on the concept of "computerphobia" (Rosen, Sears, and Weil, 1987), which is based on the dimensions of computer anxiety, computer attitudes, and computer cognition and feelings. In order to measure acceptance of these applications, and to accumulate knowledge to this end, the appropriate frameworks need to be applied consistently in future research to track eFED acceptance meaningfully.

Despite the advantages that some eFEDs have over others, some prefer still to use the paper method. Lu, Pearson, Renker, Myerburg and Farino (2006) found that nine out of twenty-two participating families preferred the paper-based diary over a PDA-based diary. Shay, Seibert, Watts, Sbrocco and Pagliara (2009) found that an equal amount of participants (33% each) preferred web-based, paper-based and mobile-phone based diaries. Furthermore, participants that used their preferred method were more adherent to recording both food intake and exercise than those who used a non-preferred method, by 64% and 66%, respectively.

Outcomes

The successful achievement of desired outcomes is a measure of the success of an information system (IS). The DeLone-McLean model of IS success (DeLone and McLean, 2003) is widely regarded as the framework in which to measure the success of information systems. Success in this case is the ability to deliver information accurately and efficiently, while conveying the intended meaning of the information, and producing a desired effect. The refined version of this framework consists of six interrelated categories that are used to evaluate IS success: system quality, information quality, service quality, use (or intent to use), user satisfaction and net benefits. The *net benefits*, or outcomes, of use of the system can consist of any variable or number of variables that is of interest to the research. For example, Yusof et al. (2008) state that net benefits can be assessed by measuring diabetes-related control, low error rate or patient satisfaction.

Identifying the desired outcomes is important when using eFEDs. Obesity related goals, including metrics such as reduction in weight, Body Mass Index (BMI) and waist circumference, are identified as desired outcomes (Burke, Conroy, Sereika, Elci, Styn, Acharya, Sevick, Ewing and Glanz, 2010). Identification of problem behaviors, such as binge eating, is also seen as an outcome that in turn contributes to weight loss (Burke et al., 2005; Timmerman, 1998) Furthermore, behavioral change is another desired outcome, specifically the increase in exercise and the reduction of unhealthy eating habits, such as decreasing intake of heavy meals and foods (Mattila et al., 2010). Desired outcomes of Web-based weight therapies also included changes in dietary intake, increased physical activity, attendance to various weight loss sessions, comfort with technology, and adherence to self-monitoring (Wantland, Portillo, Holzemer, Slaughter and McGhee, 2004).

Mixed results have been reported in the assessment of the criterion-related validity of self-reported weights. Wantland et al. (2004), in a meta-analysis involving the use of eFEDs and behavioral outcomes, found insufficient documentation of validity or reliability. Mattila et al. (2010) found that self-reported weights generally underestimated pre- and post-study weights taken by a nurse. A similar method was also recommended to increase the validity of self-reported weights by Carter-Edwards et al. (2009). Shay et al. (2009) argues that validity of weight measurement may not be important in certain situations, for instance when the desired outcome is behavioral change.

FUTURE RESEARCH

By viewing the current knowledge gaps on eFEDs, one can see that, although there are some promising results, much more research must be done to demonstrate the issues associated with their use. As well, one would notice a lack of agreement on the appropriate frameworks that can inform eFED research. Application of such frameworks in an integrated fashion may allow researchers to explore issues associated with use of eFEDs in different contexts, at different stages of behavioral change, or at points in time where risk of relapse is high.

Continuity

An objective of future research must be to improve the continuity of eFED use, as it is positively linked to desired outcomes. However, conceptual clarity with respect to a widely accepted definition of adherence is needed. In order to inform continuity-related issues, increased focus on relapse and coping must be considered. Theories pertaining to Relapse Prevention (RP; Marlatt, 2005; Marlatt and George, 1984) may offer a valuable perspective for the issue of continuity. A relapse is defined generally as "a breakdown or setback in a person's attempt to change or modify any target behavior" (Marlatt, 1985, p. 3). In the original cognitive-behavioral RP model, Marlatt (1985) conceptualized a relapse occurring at a high-risk situation, when the individual responds with an ineffective coping response, thereby reducing self-efficacy, and increasing probability of future relapse. If the individual responds to the high-risk situation with an effective coping response,

self-efficacy is increased and the probability of future relapse is reduced. In the revised model proposed by Witkiewitz and Marlatt (2004), high-risk situations are elaborated upon, and are proposed to include stable determinants of risk (such as family history and social support) as well as contextual (such as cues and geographic location). As well, coping behavior has reciprocal relationships with both cognitive processes (such as craving and self-efficacy) and frequency of desired or undesired behavior; as an example, good coping behavior is enhanced by both a low amount of undesired behavior *and* a high degree of self efficacy.

Evaluating the Application Itself

Evaluating the acceptance of eFEDs has not been widely performed, as identified earlier in this discussion. Furthermore, acceptance is not evaluated using consistent, widely-accepted methods. Established instruments for the measurement of acceptance are widely available (Davis, 1989; Venkatesh et al., 2003), and can be implemented quite easily in research. As mentioned earlier, The Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al., 2003) is a widely used model for the purpose of evaluating acceptance of technology by its users. It consists of four dimensions, which are antecedent to the behavioral intention to use the system, which is itself an antecedent to actual use. These dimensions are: performance expectancy; effort expectancy; social influence; and facilitating conditions. *Performance expectancy* is the degree to which an individual believes that use of a certain system will increase the performance in the execution of a task. *Effort expectancy* is the degree to which the individual believes that use of the system will reduce the effort needed in executing a task. *Social influence* is the degree to which the individual believes that other individuals in the organization believe it is appropriate to use the system. *Facilitating conditions* measures the degree to which the individual believes that the organization supports the use of the system by means of technological and organizational infrastructure. These four variables are moderated by age, gender, experience, and voluntariness, which mean that the presence of one or more of these conditions can influence the score of the variables.

Evaluating Effects on the User

The by-and-large purpose of eFEDs is to manage weight; therefore, improvement in weight related indicators, which are quite easy for most people to measure, should be an important desired outcome of these diaries. However, if behavioral change is considered, a larger framework is required to understand the role of an eFED in a larger behavioral change process. One such framework is the Health Action Process Approach (HAPA; Schwarzer, 2008; Schwarzer and Renner, 2000). This framework advances previous behavioral change models by addressing the theoretical gap between the precedent intention and antecedent behavior (Sheeran, 2002). The HAPA framework proposes that an additional period of planning takes place after intention is formed, but before actual behavior. Self-efficacy (Bandura, 1977; Bandura and Cervone, 1983) is an integral part of this framework. Self-efficacy is the belief that one is confident of reaching a defined goal or performing a certain behavior. It is derived from positive feedback, persuasion and vicarious experience, and in turn, is precedent to positive behavioral change. Three different types of self-efficacy are required for positive behavioral change in the HAPA framework: *action self-efficacy* is the confidence that the appropriate outcomes can be achieved. This type of self efficacy is important in forming the intention to initiate behavior to the desired end, along with positive *outcome expectancies* of the desired behavior, and *risk perception* of continuing undesired behavior. After intention is formed, both *maintenance self-efficacy* and *recovery self-efficacy* are important in sustaining desired behavior. Maintenance self-efficacy is the belief that one can overcome barriers in executing a plan, and recovery self-efficacy is the belief that one can resume the desired behavior, if a barrier were to succeed in preventing desired behavior.

PRELIMINARY RESULTS

This paper presents knowledge gaps associated with the use of eFEDs, and proposes several pertinent theoretical frameworks in which to evaluate issues associated with continuity of use, acceptance and capacity to induce behavioral change among its users. Currently, a mixed-methods, sequential explanatory, study is being developed, for the purpose of determining barriers and facilitators of adherence to eFEDs. In the first phase, a quantitative survey will take place, in which overweight and obese participants (Body Mass Index > 25) will use an eFED. The proposed research model (See Figure 2, below), which will be constructed from the aforementioned frameworks, will be validated in this phase. Both technology acceptance (effort expectancy and performance expectancy) and health action-related variables (risk perception, outcome expectancies and action self-efficacy) contribute to forming intention on both actual usage of the eFED, and associated changes in behavior. Both maintenance and recovery self-efficacies contribute to planning behavior as well as adherence to use of the diary. Outcomes, whether positive or negative will impact the self-efficacies and outcome expectancies associated with changing health behavior, as well as the performance expectancy of the technology itself. In the second phase, qualitative interviews will be used to explore the determinant themes to adherence to eFEDs in the proposed theoretical model, as well as any emerging themes, using outliers or extreme cases from the first phase.

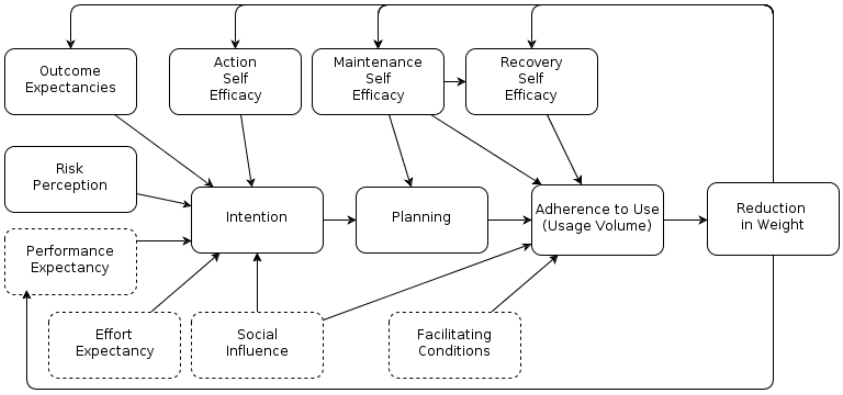

Figure 2: Both attitudes about health behavioral change (outcome expectations, risk perception, action self-efficacy, maintenance self-efficacy and recovery self-efficacy) and the technology (dashed boxes; performance expectancy, effort expectancy, social influence, facilitating conditions) are precedent to forming the intention to adopt the technology and related processes, performing planning and desired behavior activities. The desired behavior will produce outcomes, which will in turn feed back to enforce several of the precedent variables.

Pretesting eFEDs via a convenience sample of a few participants revealed potential insights. For example, two participants that logged on 34.4% and 35.5% of the days within the 90-day period lost 10.2 and 9.7 pounds, respectively. A visual inspection of the data revealed a sporadic logging pattern, a week typically having from 2 to 5 days with no food or exercise data collected. The other two participants quit using the diary after 7 and 9 days, respectively. These results raise some interesting questions. For users who collect data sporadically, what causes the disruption, and what factors allowed the users to maintain use after a short period of disuse? Also, does positive behavior last during these short periods of disruption, or does disuse of the diary equal disruption in health behavior? Perhaps some of the features whose purpose to facilitate adherence (reminders, etc) had an impact on recovery? In the case of the last two, it seems that there may be an initial adoption period in which acceptance is critical. What are the barriers to adoption in this early phase of use?

The general sense from the pretest data demonstrated viability with respect to the hypothesized links depicted between variables in the research model. Facilitators of adherence identified were presence of positive social influences, and visibility of results. Barriers to adherence identified were peer pressure, life routine disruption, and lack of positive social influences. A formal evaluation of eFEDs has been designed to be rolled out in the coming months, pending approval from ethics board review. Results of this research will be made available to academic circles through journals, conferences and workshops whose domain is relevant to obesity and e-health.

CONCLUSION

eFEDs provide a low-cost method to reduce the strain on any healthcare systems, especially those challenged with a high prevalence of obesity, such as in the US and Canada. In closing, we note that eFEDs provide a technology that is still poorly evaluated. Research connecting the key constructs and applying the same measures for the same study effects reliably and consistently is needed to enable intelligent comparisons of research findings within a developing body of knowledge. The eFED application must be seen as a component within an integrated theoretical framework in order to assess issues related to continuity of use, the tool's acceptance by the user, and its capability to induce behavioral change.

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