Designing User Interfaces for Ecological Momentary Assessments for Superior User Engagement: A Theory Driven Approach

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Abstract
Most mhealth applications send motivational messages without regard to the individual's current physical or emotional context. Ecological Momentary Assessments (EMA), in contrast, allow for real-time self-reports that can guide more timely and appropriate behavioral interventions. However, many mhealth assessments suffer from poor user adherence. We hypothesize that EMA survey interfaces with appropriate level of media richness improve user adherence and reduce cognitive load. Guided by Media Richness Theory and Cognitive Load Theory, a 3-group (n=90), 12-week randomized experiment will evaluate user engagement and cognitive load of 3 sets of EMA survey interfaces representing 3 different levels of media richness. Our study will determine the effect of media richness on the user engagement and cognitive load in the context of EMA surveys. Insights generated by our study can help interface designers’ in choosing the appropriate media for designing superior EMA survey interfaces.

Keywords
Ecological momentary assessment, graphic user interface, media richness, cognitive load.

Introduction
EMA refers to the collection of behavioral, physiological, or self-reported data in nearly real time and in a person's natural setting so that the procedure of capturing data is less susceptible to recall bias and is more sensitive to contextual factors that may influence variables of interest (Brannon et al. 2016). It examine the dynamic relationships between individual behavior and the social and physical contexts in which they occur (Burke et al. 2017). Context-sensitive EMA can be crucial for individuals trying to self-manage chronic illnesses with the support of a mhealth application. Although EMAs offer methodological advantages over traditional retrospective surveys, the benefits can be diminished by participant nonadherence (Dunton 2017). Therefore, designing EMA survey interfaces that engage the users to respond consistently is important. To the best of our knowledge, no specific guidelines for interface designers exist that facilitate the development of engaging user interfaces for EMA self-report surveys. Our study will address this issue with the guidance of two theories. These two theories are 'Media Richness Theory' (Daft and Lengel 1986) and 'Cognitive Load Theory' (Sweller et al. 1998).

Varying levels of media richness provide different amounts of cues for the transfer of information through user interfaces. While rich media offers more clues for the transfer of information, it may also impose a greater cognitive load to the users as different types of information (like visual and verbal) are processed differently and along distinct channels in the human brain. In this particular context, the research question considered in this paper is: What is the effect of media richness in interfaces for EMAs on user engagement over the time? We will address this research question by designing and testing sets of EMA survey interfaces.
with three different levels of media richness with a cohort of users with chronic disease using a mhealth intervention to assist with managing their chronic disease with the help of healthy eating, physical activity, and stress management.

The proposed study has clear theoretical and practical contributions. Theoretically, the study is expected to reveal the effect of media richness on the users’ long-term engagement in terms of sustained EMA survey responses and their cognitive load. Practically, our study findings can contribute to a consolidated set of design insights that can offer detailed suggestions to the interface designers for the development of EMA survey interface screens that improve user engagement.

This paper is organized as follows. In the literature review section, we briefly describe EMA, media richness theory (MRT), cognitive load theory (CLT) along with evaluation of user engagement. We discuss the EMA instrument development and the experimental procedure in the methodology section. Finally, we conclude with a section discussing the contribution of the study.

**Literature Review**

**Ecological Momentary Assessment**

The growth in EMA studies has expanded the range of behaviors being studied (Dunton 2017). There are three specific reasons behind the growing use of EMA surveys. First, the wearable sensors and applications that objectively track user physical activities often fail to capture valuable contextual information such as activity purpose, mood, and the social and physical environment (Barrigón et al. 2017). Second, EMAs cues on behavior by examining the mechanism through linking the immediate environment with behavior. Last, EMAs are often more useful than conventional instruments of retrospective questionnaire-based survey methods because they sample environmental influences on behavior in real time (Dunton 2017). EMA survey data can provide different insights from traditional retrospective measures. Despite the growing research on EMAs as a survey method, most of the studies used text messages to assess health information needed (Dunton 2017). Though researchers (Tsai et al. 2007, Schnall, et al. 2013) suggested that usability and proper communication channel is a key factor for both assessment and intervention functions, there exist scant studies that evaluate the effect of media richness on sustained adherence to EMA surveys.

**Media Richness Theory**

We used Media Richness Theory (MRT) as the prime theoretical lens for our study. MRT suggests that different communication media vary in their ability to enable users for effective communication (Dennis and Kinney 1998). ‘Media Richness’ is defined by Daft and Lengel (1986) as “the ability of information to change understanding within a time interval.” Media Richness juxtaposes all the communication media on a continuous scale, based on their abilities to communicate complex messages adequately. However, one should note that rich and lean media are not exact opposite poles of a continuum. While a rich media may be considered “preferred” for communicating a particular message, a leaner media may also communicate the message adequately. Based on the richness of the media a sender can expect different levels of user engagement. According to Dennis and Kinney (1998), the primary driver in selecting a communication medium for a specific message is the reduction of potential misinterpretations of a message. The more equivocal a message, the more time and cognitive processing are required for correct interpretation. For example, a simple task of communicating a question intended to identify a current physical activity could be communicated through a short text-based user interface or through a user interface using a combination of texts, icons, and auditory signals. These two user interfaces provide different levels of media richness. MRT implies that a sender should select a medium of appropriate richness to communicate the desired message that will fulfill a specific task. Based on this theory, we suggest the following proposition:

Proposition: (1A) Users responding to EMA interface screens with higher media richness will send significantly higher number of responses than users responding through EMA interface screens with medium media richness or lower media richness. (1B) Users responding to EMA interface screens with higher media richness will send responses over a longer period than users responding through EMA interface screens with medium media richness or lower media richness.
Cognitive Load Theory

Cognitive load theory (CLT) has provided guidelines intended to assist in presenting information in a manner that maximize receivers’ intellectual performance (Pass et al. 1994, Sweller et al. 1998). CLT employs aspects of information processing to emphasize the inherent limitations of concurrent working memory load on learning during instruction. Therefore, use of different media (with different richness) in designing EMA interfaces are expected to impose different cognitive loads to users. CLT has broad implications for interaction design, by allowing interaction designers to control the conditions of interaction within an environment. Cognitive load can be particularly attributed to the level of media richness. For example, EMA interfaces with different levels of media richness are expected to impose different amounts of cognitive load to the users. The implication of this process is not always intuitive. As the user needs to process more information to decode content communicated through comparatively rich media, it is possible that they will face higher cognitive load than the user who has to decode the content communicated through a comparatively leaner media. However this is not always the case. High level of media richness often lead to lower cognitive load due to the presence of multiple cues and absence of ambiguity. This means that though comparatively rich media is expected to impose higher cognitive load because of its higher message density, in reality it imposes lower cognitive load because of the presence of multiple cues and higher content tailoring opportunity. Based on the CLT we propose the following proposition:

Proposition: (2) Users responding to EMA interface screens with higher media richness will experience significantly lower cognitive load than users responding to EMA interface screens with medium media richness or lower media richness.

We will use subjective rating technique to measure cognitive load as subjective ratings are more sensitive and less intrusive than an objective physiological measures (Paas et al. 1994).

User Engagement Evaluation

In our study user engagement will be captured through three objective measures: 1) Total number of valid responses for each of 3 EMA interface screen sets; 2) Average number of valid EMA responses for each of 3 EMA interface screen sets for twelve weeks and 3) Coefficient of Variation for each of 3 EMA interface screen sets. Total number of valid response for each EMA survey interface screens set will be calculated by adding the complete responses submitted by users responding to a particular set of EMA interface screens for twelve weeks. Average number of valid EMA responses for each EMA interface screen set will be calculated by dividing the total number of valid response for each EMA interface screen set for twelve weeks. Coefficient of Variation is a measure of relative variability. It is the ratio of the standard deviation to the mean. Figure 1 depicts the conceptual framework of our study.

Methodology

We will deploy EMA survey interfaces through a mobile application platform with a sample of the middle-aged patients who are self-managing coronary heart disease (CHD). Over a 12-week period we will record user responses for each of the three different EMA survey interface sets. EMA survey questions will collect information about self-reported physical activity, sedentary behavior, eating episodes, stress level and
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immediate physical and social environment. All participants will be informed of the information gathered by the application, the purpose of the study, and the data purging process; written informed consent will be obtained from all participants.

**EMA Instrument Development**

Following an iterative design process, three different sets of for EMA survey interfaces corresponding to three different levels of media richness are designed. To ensure that each set of EMA survey interfaces represent their corresponding level of media richness we will do the manipulation checking of our instrument with adequate number of student subjects. Table 1 shows examples of twelve EMA survey interface screens of which the first row illustrates comparatively low level of media richness, and the second...

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<th>Table 1. EMA survey interface screens with three levels of media richness.</th>
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<th>EMA survey interface screens with lower level of media richness (Text Only).</th>
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<th>EMA survey interface screens with moderate level of media richness (Text+Icon).</th>
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| EMA survey interface screens with higher level of media richness (Text+Icon+Audio). |
and third rows representing medium and higher level of media richness, respectively. It also provides the details of different interface elements used in the development of the different sets of EMA survey screens. Each EMA survey sets contains 12 interface screens representing questions about current physical activities, locations, eating episodes, stress level, and social context. User responses will be captured through two objective measures mentioned above. Cognitive load will be measured by using a subjective rating technique suggested by Paas et al. (1994) after making required modification of the existing items.

**Experimental Procedure**

A group of ninety users (30 in each group) with a history of CHD will be randomly assigned to one of the three EMA interface screen sets with varying levels of media richness. During the twelve-week study period, users will use the mobile application to respond to the EMA surveys. Each participant will receive a mobile-based a 10-item cognitive load questionnaire at the end of 6 and 12 weeks of the experimental trial. At the end of the twelve-week experiment, participants will be asked to complete a post-experiment questionnaire regarding their overall experience with the EMA interface screens.

**Contribution**

The study has clear theoretical and practical contributions. Theoretically, the study is expected to reveal the effect of media richness on the user engagement and cognitive load. It will facilitate an understanding of the interplay between media richness and cognitive load in context of EMA survey responses. The study will also provide practical help to interface designers’ regarding the selection of communication media for designing context-specific EMA survey interfaces with appropriate media richness. Finally, considering the current trend of suboptimal average adherence rates estimated among mobile-EMA studies, using EMA survey interfaces with appropriate media richness can offer a higher average engagement rate.

**References**


