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Ecological Momentary Assessment in Research Methodology: A Literature Review

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Abstract

Introduction: Ecological Momentary Assessment (EMA) is a real-time data capture longitudinal methodology which is conducted through smartphones or wearable sensors. This methodology uses prompts to gather information on the current state, behavior and experience of a person in their natural environment. The purpose of this study is to explore the feasibility of using EMA as a methodology in measuring behavioural contexts around physical activity.

Utility: EMA is advantageous in reducing recall errors, enhancing the validity of self-reports by actively recording a participant's dynamic interaction with their environment, while accounting for intra- and inter-personal variation. EMA can provide researchers with more accurate information that is generalizable to real-life routines, and provides insight on processes that can undermine behavior change. Additionally, EMA is convenient due to the omnipresent accessibility of smartphones or related technologies, which are easy to use and can quickly collect data from large populations remotely. The use of EMA can answer researchers' questions regarding participant current context, affective states, and psychological processes. This can ultimately help create innovative and feasible solutions which can be implemented into participant's natural environments and daily lives to benefit their physical, mental and emotional well-being.

Challenges: EMA requires smart technology equipment which can be expensive to supply, repair, or replace. Real-time prompts pose the challenge of subjects' full compliance to prompts, struggling to respond in the case of competing activities, not carrying the device or device malfunctions such as battery drainage or software problems. Moreover, EMA raises concerns in its practicality with low-socioeconomic populations that cannot afford such technology, elderly populations who cannot operate these devices, or clinical populations whose psychopathology may interfere with their responses.

Limitations: The use of EMA is associated with biases concerning ecological validity. For example, consistent prompts on a certain activity may cause an individual to think about the activity more or alter their behavior. In the absence of researchers, it is difficult to verify data reported by participants. It is possible to mitigate such biases by seeking confirmation through reliable sources who are in contact with the participants, to approve a subset of the data.

Keywords: ecological momentary assessment; EMA; physical activity; exercise

Introduction

Physical activity (PA) is an important daily component of human health and wellness that has been shown to reduce the risks of serious illnesses, such as coronary heart disease, type 2 diabetes, and cancer [1, 2]. Despite these benefits, many individuals on a global scale do not meet the daily recommendations for PA [3]. Thus, a better understanding of the factors that influence PA and the development of lifestyle interventions which can promote PA is needed [1, 4-5]. To do so, data regarding individuals' PA that is both unbiased and accurate is required. Typically, this has occurred using retrospective measures such as self-reported questionnaires. However, retrospective measures pose cognitive limitations such as accurate memory recall about PA duration, frequency, and/or intensity [1, 5]. Additionally, it has been shown that retrospective measures can result in over-reporting of PA volume by respondents due to the social desirability effect, where a participant's responses are based on their desire to be perceived as active [5]. Although device-based measures, such as the use of pedometers or accelerometers, confront the aforementioned challenges by directly capturing data, they fail to recognize different types of PA (eg. swimming or walking), or other contextual information such as the domain (eg. leisure, transit, etc.), physiological demand (eg. anaerobic versus aerobic), location, or social atmosphere (eg. alone or with a trainer) [5]. This information is critical to developing effective PA interventions, where behavior has been shown to be an interaction between individual and contextual factors [3,4].

Research regarding the determinants of PA have traditionally focused on social-cognitive theories, analyzing cognitive, social and environmental factors. However, a lesser focus has been placed on understanding the psychosocial determinants of PA, such as affect [6]. In order

to better understand and change human behavior, interventions must be applicable to human momentary states (within-person processes) and groups of individuals (between-person processes) [5,6]. In recent years, ecological momentary assessment (EMA) has been increasingly used to study both within and between-individual processes. During EMA, participants receive a prompt on an electronic device, such as a smartphone, repeatedly to provide behavior information. These prompts can be signal contingent, meaning that they are sent only after a signal is picked up by a wearable device or a smartphone, or time-contingent, meaning that the prompts are sent at a specific time based on a predetermined schedule. These prompts can be sent at fixed times or at random times during the day. [3, 6]. EMA gathers information about participants' behavioral data and context, and is paired with information regarding PA to generate a more holistic image of one's PA behavior. In gathering this data, it is essential to analyze the highest-standard methodology for current and future research. Hence, this literature review seeks to investigate the utility, challenges and limitations of EMA as a methodology for collecting PA data, particularly with respect to accuracy, compliance and convenience.

Utility

With respect to assessing PA, it is ideal for a methodology to be accepted by participants, reliable in the information gathered, and effective in terms of discouraging sedentary behavior in the long term. Therefore, this review will analyze the utility of EMA based upon its acceptance, validity and intervention impact.

Convenience/Acceptance

Mobile phones and smart devices are a common asset of many individuals in present-day society. These devices can run softwares which prompt EMA surveys on the display screen and record one's responses for future reference or download. Smartphones are easy to use and omnipresent, with the ability to collect data remotely from participants in large quantities or populations [7]. Approximately 95% of Americans own a mobile phone, and almost 77% of Americans own a smartphone (77%) [1]. The flexibility of EMA also allows for data to be collected in combination with accelerometers or other objective measurement techniques to measure physical activity and other factors such as affect or mood [7]. In populations such as children or youth where research protocol may be difficult to explain, strong evidence for EMA acceptance has been demonstrated as seven out of eight children had previously used a similar type of mobile phone device and felt EMA to be unobtrusive, highlighting its ease of use for the younger population [7]. Likewise, in a study analyzing interval walking training in an adult population, participants found EMA's highly satisfactory and were shown to have a high response rate. Specifically, of the 5,936 EMA prompts sent to an active worn activity monitor, a total of 423 prompts were unanswered [8]. The ability to download apps to use as EMA also highlights the flexibility in the creation, development and technological support of software, where research groups can individualize their programs to best suit the data they aim to collect [8, 9]. A recent systematic review also showed that in most clinical studies, participants could use their own smartphone, which was either an Android smartphone, iPhone or both. Regardless of the type of phone used, all the research smartphones were able to have the target application installed and used by participants. Hence, EMA seems to be applicable with regards to the prevalence of modern-day technology use across various operating systems [9, 10].

Validity/Prompting

EMA offers the ability to reduce potential biases, such as memory recall through real-time data capture and time-stamping of responses [11]. This is an important feature of the methodology as the validity of EMA is based on momentary experiences and participants' answering prompts in the moment [9]. A clinical trial assessing EMA and PA in the adult population reported that over 66.5% of the EMA's were responded to within a minute, with only two taking longer than five minutes [9]. Further, systematic reviews show that the time or interval-contingent design was the most common sampling form [9]. Using an event-contingent study design requires a participant's clear definition of an event of interest to report. However, a review found that no clinical studies using EMA reported any event training for the users, leading to the validity of the data collected to be in question [3]. Other study designs were also based on event-contingent prompts when subjects were moving to a new location, and in a different type of land or population density. Ultimately, providing researchers information regarding PA time and distance, location and land use and population density [9, 12]. Although location-based sampling resulted in less prompts compared to time-based sampling, data collection of unique location and spatial spread occured [9]. An analysis of 32 studies using EMA demonstrated that participants had an average compliance rate of 71.6% with a range of 43–95% [9]. Moreover, it is suggested that measuring PA using EMA can capture the same PA levels which are consistent with a continuous high-frequency sensor, highlighting the accuracy of the system [13]. However, there is a gap in knowledge with regards to assessing the content validity of the items used to measure constructs such as PA. To address this, a guideline termed "COSMIN" has been developed with a methodology for evaluating the content validity of patient outcome measures [3]. Liao and colleagues also recently developed the CREMAS checklist which distinguishes specific items to be reported when using EMA [3]. Therefore, EMA seems to offer a reliable degree compliance and response rates; however, more development for content validity is required.

Intervention Impact

Overall, EMA has been found to increase subject adherence to PA programs. [8]. When comparing an experimental and control group, it was found that the experimental group who used EMA continued to be adherent of the PA intervention after the eight-week point of the study, when the control group declined in adherence [8]. The positive correlation between EMA use and PA can also be applied when the methodology is used as a co-intervention to PA or as a self-management tool [8,10, 12, 14, 15]. In addition, a recent systematic review found that, on average, one's presence in a natural environment in daily life (e.g. running in the park) and PA throughout the day is associated with positive affect and higher well-being [9, 14, 15]. It is important to note that when PA was reported as the main activity during an EMA prompt, participants engaged in less PA in the 15 min after the prompt compared to the 15 min before the EMA prompt [1]. This creates new knowledge in regards to the relationship between PA and EMA use, and allows scientists to account for this difference in data during analysis. Thus, EMA proves to be efficient in measuring PA in regard to participant adherence and as a self-management tool. Moving forward, research should explore if EMA plays a role in decreasing PA levels after prompts are answered.

Challenges

Despite its benefits, EMA presents challenges that make it difficult to employ. These challenges include repetition bias, issues around content validity and inconvenience of device use. First, being repetitively asked about physical activity may cause bias by prompting participants to think about the behavior differently or change their behavior. Not to mention, the items asked on an EMA survey, analyzed for its validity in measuring a certain variable, needs to be considered carefully. Known as content validity, items from traditional questionnaires cannot be simply used as they are not well-suited for short and repeated assessments in daily life [3]. Furthermore, the protocol of using EMA is complex and requires consideration in terms of sampling type, prompt frequency, monitoring period, and device type [3]. Hence, items need to be well-designed to collect rich data without over-burdening the participants in which case could result in missing data. It is also difficult to establish a rate of prompting which is not too high or repetitive, preventing participants from not responding or even potentially dropping out of the study. Even with good compliance, challenges of EMA also include mindless answering (e.g. choosing the first response for every item to finish faster) or handing a device to another person to complete. Data may also not be available for reasons such as participants not carrying the device when being physically active; not being able to or not wanting to respond to prompts due to competing activities; and technological issues like battery drainage and software malfunction [3]. Overall, EMA is a relatively new methodology which relies on technology; therefore, major challenges associated with this include biased responses, lack of guidance in prompt development and technological logistics.

Limitations

When comparing EMA to other methodologies, it is important to acknowledge that it gathers data in only a snapshot of time. For this reason, EMA may not allow research to gather as much ecological validity as desired. Since the data is all collected in the absence of researchers, the accuracy of the data and the true "naturalness" of participants' environment cannot be verified [3]. This bias can potentially be mitigated through seeking confirmation from individuals who the participant has frequent contact with to give supporting information that can be used to confirm the accuracy of at least some of the data (e.g. subjects' personal trainer) [3]. Hence, an important limitation of EMA is verifying that the information was inputted in a non-biased, purposeful and appropriate manner.

Conclusions

As technology advances and accessibility to mobile phones increases, EMA has surfaced in the field of scientific research as a reliable methodology in data collection. This review sought to investigate the utility, challenges and limitations of EMA as a methodology for collecting PA data, particularly with respect to accuracy, compliance and convenience. Based on the present analysis, EMA seems to be viable in gathering information about one's PA patterns and contexts behind such behaviors [1]. Findings suggest that among youth and adult participants, EMA effectively assesses PA activity, while promoting individuals to further engage with PA interventions. For example, EMA was found to perform better overall in comparison to other self-reported measures for PA such as questionnaires in terms of both correlation and agreement with PA interventions [5]. Similarly, a pilot study found that in older adults, reporting of minutes and frequency of PA using EMA had acceptable correlations to a standardized PA questionnaire for older adults [5]. These findings align with other studies, which have found EMA to be a valid tool to estimate PA when compared with an objective assessment device. Furthermore, the high compliance rates of participants (93%) to EMA in a study conducted by Knell et al. further represents EMA as a feasible methodology for collecting data from participant behaviors in daily life, over both short-term and long-term periods of time [5]. While the feasibility of EMA in the older adult population has raised some concern regarding the knowledge of technology, previous research has demonstrated that this population is enthusiastic about engaging with technology and can successfully implement this into their daily lives after training [1]. EMA also poses some limitations and challenges with respect to organization and development of prompts, mindless answering or validity

of responses. However, these challenges are common in self-reporting measures, and can be mitigated as more researchers become familiarized with EMA itself. Generally, previous and current findings of this review support the validity of EMA in measuring PA.

Exercise remains a key element in preventing a variety of diseases. Hence, being able to effectively gather data regarding PA is crucial to further promote an active lifestyle and prevent sedentary behavior to ultimately result in a healthier society. EMA is particularly important in research methodology, as the real-time and direct assessment of PA can prevent many of the biases commonly seen in self-reporting of PA that results in overestimation [2]. Not to mention, EMA confronts the challenge of device-based PA assessment which requires costly equipment and prevents the collection of data on the contextual circumstances of PA. With more accessible, convenient, and high-value information of PA, more effective interventions can be developed based on each individual's daily life. Therefore, EMA is significant in that its advantages are crucial in decreasing sedentary behavior, and heightening quality of life for individuals through better overall health [2]. With these current findings, future development in EMA methodology seeks to target its functionality in different populations such as clinical populations. Additionally, future research in EMA also seeks to discover the efficiency of the methodology in collecting data from participants on an international level. For example, collecting PA data from individuals in various countries globally. By examining EMA within different populations, demographics and locations, we have the ability to discover new influences that PA may have on behavior, and that behavior or affect may have on PA, for each individual. Therefore, providing a method for increasing regular exercise, and regulating one's behavior or affect [14].

Aside from this, EMA should also be analyzed in measuring other variables than PA. Future research should seek to investigate the application of EMA in other domains such as nutritional sciences, pedagogy or pharmaceutical sciences. For example, EMA use has been suggested in the field of psychopharmacology. In a situation where a noradrenaline reuptake inhibitor is more effective than a serotonin reuptake inhibitor in benefitting social adaptation, EMA methodology is proposed to be ideal in identifying the clinical efficacy [16]. The concept of using EMA for physical activity should also be applied to clinical populations to further understand its applicability. Future EMA research should also seek to understand the applicability beyond medicine or healthcare, such as in the case of gathering data regarding equality in the workplace or most influential teaching methods of teachers. The understanding of EMA as an interdisciplinary methodology will broaden the opportunities within research, such as promoting multi-institutional projects from leaders around the globe. As more information is discovered about the EMA methodology and its use in research, it is with optimism that EMA can be used to enhance the quality of life of individuals and promote their well-being hereafter.

List of Abbreviations Used
EMA: ecological momentary assessment
PA: physical activity

Conflicts of Interest
The author(s) declare that they have no conflict of interests.

Ethics Approval and/or Participant Consent
No ethics approvals or participant consent was needed in conducting this literature review.

Authors' Contributions
RB: made contributions to the design of the study, collected and analyzed data, drafted and revised the manuscript, and gave final approval of the version to be published.

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