Review

Using Ecological Momentary Assessments to Understand How Daily Fluctuations in Psychological States Impact Stress, Well-Being, and Health

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Review

Using Ecological Momentary Assessments to Understand How Daily Fluctuations in Psychological States Impact Stress, Well-Being, and Health

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Abstract: Despite great interest in how dynamic fluctuations in psychological states such as mood, social safety, energy, present-focused attention, and burnout impact stress, well-being, and health, most studies examining these constructs use retrospective assessments. Here, we discuss how ecological momentary assessments (EMAs) address methodological issues associated with retrospective reports, able to reveal dynamic associations between psychological states at small timescales that are often missed in stress and health research. In addition to helping researchers characterize daily and within-day fluctuations and temporal dynamics between different health-relevant processes, EMAs can elucidate mechanisms through which interventions reduce stress and enhance well-being. EMAs can also be used to identify changes that precede critical health events, which can in turn be used to inform the delivery of ecological momentary interventions (EMIs of just-in-time interventions) that prevent such events from occurring. To enable this work, this narrative review provides examples of scales and single-item questions used in EMA studies, makes concrete recommendations for researchers seeking to employ EMAs in their research, and discusses limitations of EMA methods. In doing so, we aim to encourage the use of these methods in research given that, when used carefully, EMA methods are well-poised to greatly advance our understanding of how intrapersonal dynamics affect stress levels, well-being, and human health.

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Researchers frequently use scales that assess psychological states retrospectively (e.g., "Over the last two weeks, I felt...") or as a trait (e.g., "In general, I..."), even though many psychological states fluctuate dynamically both between and within days (e.g., [1-5]). In turn, there is strong evidence suggesting that these dynamic fluctuations in psychological states influence how individuals interpret and respond to ambiguous events in their daily lives [6-8]. Imagine a scenario, for example, in which all of your co-workers were invited to a happy hour after work, but you were left off the invitation. If you are in a positive mood, you might perceive this as an oversight; however, if you are in a more negative mood, or in the aftermath of a night of poor sleep, you might perceive this as a purposeful exclusion or a deliberate attack. Because people experience ambiguous events every day—and given that subjective experiences and appraisals of events have been found to be a stronger predictor of psychological and biological impacts than more objective assessments of events [9-10]—it is important to better understand how fluctuations in important psychological states influence not just how individuals experience specific events, but also how these changes relate to biological and clinical states over time.

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Historically, it has been challenging to capture dynamic variation in psychological states that influence people's stress, well-being, and long-term health in controlled laboratory experiments. This is due, in part, to the time restrictions and arbitrary settings that reduce external validity inherent to laboratory research and traditional ways of collecting data. In contrast, ecological momentary assessments (EMAs) involve scheduled data collection to be completed outside of the lab in a participant's naturalenvironment, enabling researchers to assess daily, ecologically-valid experiences and fluctuations in psychological states in real-time. EMAs can be especially useful when trying to assess associations between psychological states and dynamic outcomes such as stress, well-being, and health, which are hard to adequately assess using infrequent measurements. Here, we will discuss how EMAs are especially useful to those seeking to understand how dynamic fluctuations in psychological states impact stress, well-being, and health. Specifically, we will highlight what is known about how one's mood, social safety, energy levels, present-focus, and burnout influence stress, well-being, and health, and provide examples of how these constructs have been assessed in past studies. Finally, we will discuss limitations of EMAs, provide recommendations for researchers seeking to employ EMA methods, and discuss future research directions.

EMAs

EMAs have been in use since the 1990's, although their use has become far more common and effective as they have largely become digital in recent years (see Figure 1 for a visualization of the increase in publications that contain the term "EMA" over time). Today, EMAs are short surveys digitally sent to participants to be completed in real time, as they are experiencing the events they are reporting about in the context of their everyday lives. Participants can be assessed at random intervals or in conjunction with key events of interest. Often, EMAs assess people's thoughts, feelings, or behaviors, although any variables of interest can be measured. Advantages of EMA survey methods include the reduction of recall bias and erroneous reporting due to forgetfulness, their ecological validity, and the use of repeated assessments over time, the latter of which enables investigations of complex, within-person, temporal interactions between processes such as mood, stressful life events, and health behaviors [11] Further, the use of EMAs also removes concerns associated with between-person confounders, reduces concerns about time-varying confounders, and can reduce the downward bias on effect sizes induced by overly long assessment lags [12].

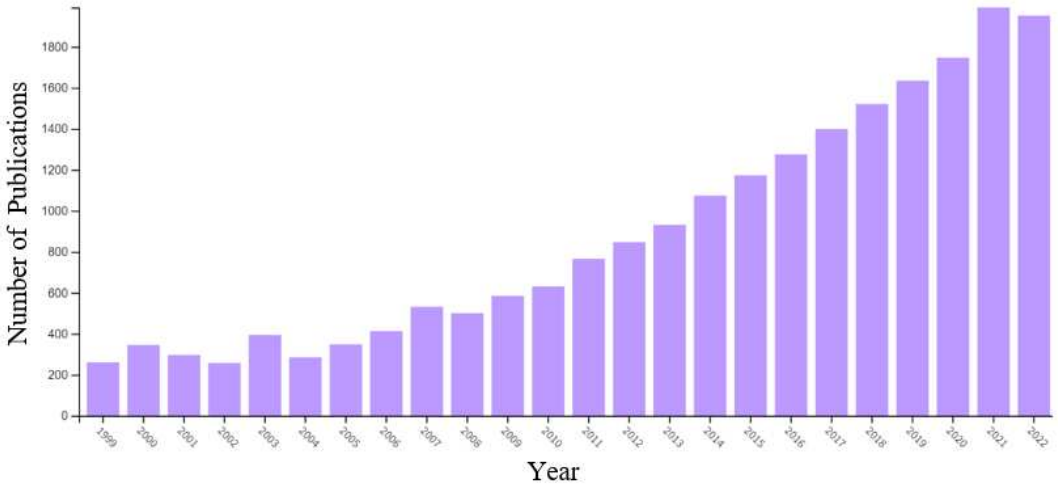

Figure 1. The number of publications containining the term "EMA" has increased over time. Visualization created using Web of Science.

Many EMAs are sent to participants as notifications on smartphones and thus assess states in real-time. In Figure 2, we show how EMA questions may be presented to participants via smartphone (based on examples from [13-15]). However, other EMA methods are similar to a daily diary method, where participants respond to prompts once per day, reflecting upon their day in general, as opposed to their current state. Finally, EMAs can also be paired with sensing technology using a smartwatch

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[16], which can enrich these assessments by pairing them with a participant's physiological state (e.g., heart rate, blood pressure, and galvanic skin responses), objective behaviors (e.g., activity levels, social interactions, and sleep), and location.

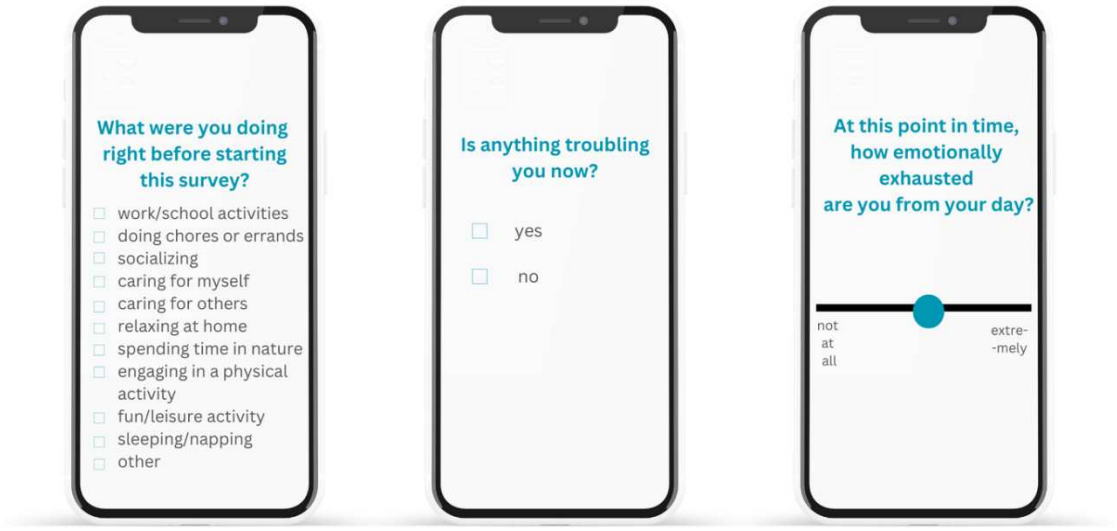

Figure 2. Examples of Ecological Momentary Assessments conducted using mobile devices.

Psychological States

Although many psychological states and their daily fluctuations impact stress and well-being, some states have been consistently and strongly related to stress levels, well-being, and health, and are thus particularly important to measure at a high frequency in participant's daily lives. First, we discuss well-being and stress. Next, we review key studies that have used EMA methods to investigate how one's dynamic changes in mood, energy levels, social safety, present-focus, and burnout are associated with stress levels, well-being, and health.

Well-Being

Well-being is associated with health-promoting outcomes, including enhanced physical and mental health [17]. Well-being contains both a subjective component, which is often assessed with life satisfaction and affect measures, and a psychological component, which is often conceptualized as thriving and finding meaning in life [18]. Rather than being just the absence of negative factors, well-being is better conceptualized as the presence of positive factors. Well-being predicts health, happiness, and longevity [17]. Although well-being is somewhat more stable than other psychological states (e.g., stress levels) over time, well-being also varies across time and contexts in ways that are overlooked by traditional single time point well-being measures [19].

In studies specifically assessing within-person fluctuations in well-being, well-being is positively associated with being in nature and engaging in physical activity, and negatively associated with being at work (see [14] for review). However, well-being in EMA studies is typically assessed with a brief measure of positive affect or subjective happiness [14, 20], as opposed to a more comprehensive measure of eudemonic well-being that assesses aspects of growth, thriving, or meaning. Further, many past studies have used limited statistical analyses that fail to isolate within-person effects, instead focusing on between-person effects or relations that collapse between and within-person effects. As one of the largest benefits of employing EMA methods is the rich, within-person data collected, it is important to pair EMA data with complementary analytic methods to realize their full potential.

Stress

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Stress refers to a person's subjective experience of being able to manage the tasks in their lives, and not to a specific stressful experience, which is called a stressor. Although some amount of stress is generally considered to be positive in a person's life [21], high stress levels, especially over long periods of time, take both a physical and mental toll on an individual [22-23] for example, whereas acute stress is a very strong predictor of PTSD and depression, chronic stress dysregulates biological processes that cause or exacerbate a wide variety of disorders, including anxiety disorders, depression, psychosis, asthma, ulcers, diabetes, certain cancers, and autoimmune and neurodegenerative disorders [24-25]. In fact, nine of the top ten causes of death in the United States today are caused or exacerbated by stress [26].

Due to the high prevalence of chronic stress and its negative impact on health, many interventions have been designed to reduce stress levels and improve stress-related health outcomes (e.g., [27-29]). Assessing the success of these interventions is typically done using follow-up surveys administered 1-12 months following the completion of the intervention (e.g., [30]), in which participants indicate their stress levels over the last week or month. However, sparse assessments like these fail to capture the dynamic nature of stress, well-being, and health; moreover, they can be influenced by a person's current psychological state in ways that can bias participants' experience over the last month. Infrequent assessments thus limit our understanding of how interventions impact people's daily fluctuations in psychological states, preventing researchers from obtaining a mechanistic understanding of *how* interventions influence stress and well-being over time.

Less research has been done within non-clinical populations to assess daily fluctuations in stress levels compared to those assessing well-being, preventing generalized findings about how stress varies in association to time or context, broadly. However, evidence is emerging that stress levels are especially dynamic [2, 31-32], with a large amount of variability day by day, as well as over the course of a day. Further, stress levels are affected both by the number and severity of stressors experienced, along with a wide range of psychological states. Resilience, or how well people manage stressors, is associated with less negative affect in response to stressors (as assessed by EMAs), specifically in individuals who have experienced early life stress [33].

Mood and Affect

Positivity of mood and affect measures are so strongly related to well-being that they are often used as a proxy for assessing well-being itself. In college students, for example, researchers have found that daily levels of positive affect are negatively associated with both daily levels of self-reported stress and the perceived stress scale, and positively associated with flourishing, a measure of well-being [34]. Beyond just levels of positive affect, variability in affect is also associated with well-being. Ong and Ram [1] reviewed how affective variability, instability, inertia, and reactivity influence health outcomes and well-being, above and beyond general levels of positive affect. They suggest that those with fragile high positive affect (i.e., positive affect that, while sometimes high, is also highly variable) might not experience the same good health as those with more stable high positive affect, although this can be missed in traditional research designs. In support of this conclusion, another team of researchers using EMAs found that experiencing decreases in the positivity of one's mood (i.e., positive affective reactivity) following a stressful life event predicted an increased mortality risk about ten years later, whereas neither negative affective reactivity to stressors nor general levels of positive affect influenced mortality risk [35]. Specifically, a one unit increase in positive affective reactivity predicted a 132% increase in mortality risk. Studies such as these highlight the added value of using EMA methods to assess how daily fluctuations in mood and affect impact stress, well-being, and health.

Social Safety

Humans are inherently social creatures, and our social interactions and their quality influence our stress levels and well-being by influencing perceptions of social safety [36-38]. Whereas social safety, connectedness, and inclusion predict positive life outcomes, loneliness, social ostracism, and social isolation predict negative health outcomes, reduced happiness, and reduced longevity [39-42]. Research using EMA methods and sensing data have revealed that daily social interaction (both conversation frequency and duration) are associated with lower levels of perceived stress, more so than levels of social interaction averaged across days [34], highlighting the advantages of assessing

daily levels of social interaction using EMA methods. In a group of older adults living with HIV, researchers found that despite social interaction being associated with higher pain and fatigue ratings later that day, participants were happier when they spent time with others compared to when they spent time alone [43]. Likewise, by assessing participants three times per day for six days, researchers found that people felt more happiness and interest, and less sadness, tiredness, and pain, during assessments taken when they were engaged in a social interaction versus those taken when they were alone [44]. Finally, during COVID-19 lockdowns, [45] used EMA methods to investigate the impact of face-to-face social interactions on mood and stress in real-time and found that having at least one social interaction preceding an assessment predicted more positive mood, more calmness, heightened energetic arousal, and reduced stress compared to assessments when no social interactions were reported. These within-person effects persisted even while controlling for people's mood and stress levels reported in the previous assessment, indicating that social interaction, and not pre-existing psychological states, were driving these effects. Because social interactions have a large impact on stress, well-being, and health, they are also important to consider in studies assessing health-related outcomes. Further, because social interactions vary in their frequency, duration, and quality across moments and days, EMA methods are especially well-suited to assess social interaction and support in real-time.

Energy and Arousal

Another state which varies considerably from hour-to-hour is one's energy and arousal levels. In children, researchers have found that high energy levels and low levels of tiredness over 30 minutes predict moderate-to-vigorous physical activity, which, in turn, predicts more positive affect, less negative affect, and increased energy [46]. One strength of using EMA methods to assess these associations is that researchers are able to understand the temporal relations between mental states and behaviors. In this study, for example, energy levels both predicted, and were predicted by, physical activity. Researchers have also used EMA methods to assess associations between exposure to childhood trauma and daily energy levels, finding that the more childhood trauma a person has experienced, the lower their momentary energy levels [47]. Additionally, those with more childhood trauma exposure also reported heightened anxiety, loneliness, perceived daily hassles, and use of maladaptive coping strategies, alongside reduced psychological well-being, life satisfaction, optimism, sense of coherence, self-efficacy, and perceived social support. One unexplored possibility is that daily energy levels may be one factor that mediates associations between childhood trauma exposure and mental health outcomes.

As shown here, the use of EMA methods can help improve our understanding of complex associations between psychological states and stress, well-being, and health by revealing the exact temporal relations between these processes, and by facilitating the discovery of psychological mechanisms that might mediate or moderate associations between things like childhood trauma exposure and mental health outcomes. Further, EMA methods can help investigators determine how interventions impact people's daily psychological states. For example, [48] found that daily arousal was increased in participants who completed a mediation-based intervention after six months of training, postulating that elevated arousal might be one mechanism through which mediation training can improve people's quality of life. EMA studies such as these can overcome temporal hurdles inherent to traditional studies which prevent true assessment of mediation of effects, helping to uncover the mechanistic processes through which interventions or events influence later health outcomes.

Present-Focus and Mindfulness

Being focused on the present moment is generally associated with enhanced well-being [49]. Levels of present-focus are positively associated with life-satisfaction [50] and vary dynamically day-by-day in ways which predict daily fluctuations in well-being [51]. Mindfulness interventions are designed to increase present-focus, and have been found to be associated with reduced stress level and greater acceptance and self-regulation [49], along with increased resilience, self-efficacy and well-being [52-53]. Further, researchers have found that increased daily mindful states are related to enhanced coping and reduced appraisals of stress [54].

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Other mental health interventions have also been found to increase present-focus. For example, participants who engaged in three different types of meditation-based mental training interventions (Presence-, Affect-, and Perspective-focused interventions) all exhibited elevated levels of present-focus in their daily lives after three months of training, along with an increased ability to cope with everyday stressors [48]. Using EMA methods to assess present-focus may be especially useful in intervention studies, insofar as present-focus might meditate the association between the intervention and positive outcomes in daily life.

Burnout

Burnout, a state of chronic physical and emotional exhaustion resulting from prolonged exposure to stressors, is often characterized by feelings of depersonalization and reduced personal accomplishment [55]. Burnout has become a significant concern within the contemporary workplace, with some studies reporting that more than half of American workers experience at least moderate levels of burnout [56]. Indeed, the demands of fast-paced work environments, long working hours, and increasing expectations have led to a rise in burnout rates among employees, negatively impacting their overall well-being and job performance [57], including reduced productivity, higher absenteeism, and increased turnover rates, leading to economic losses and compromised work culture [58].

Burnout is not only detrimental to an individual's psychological health [59] but also has profound implications for their physical health. For example, persistent stress and emotional exhaustion associated with burnout have been related to weakened immune system function [60] and an increased risk of cardiovascular diseases [61]. Past research in this context has used EMAs to measure burnout by asking participants to identify the extent of their emotional, physical, and mental exhaustion, along with end-of-day job satisfaction and quitting intentions [13]. By collecting real-time data through mobile devices, EMAs provide a dynamic way to track an individual's stress levels, mood fluctuations, and daily work experiences. This research has helped to identify patterns of stressors and triggers that contribute to burnout, allowing for more targeted interventions and personalized support.

Beyond using EMAs to assess burnout, Ecological Momentary Interventions (EMIs) may be a valuable strategy for preventing burnout before it occurs. EMIs, a term coined in 2005, are treatments provided to participants during their everyday life through a mobile device, either on their own or as a supplement to a different ongoing treatment [62]. EMIs intervene in one's day and environment, encouraging a certain behavior or providing feedback in real-time [63]. By delivering timely and context-specific support, EMIs provide employees with coping strategies, mindfulness exercises, and stress management techniques precisely when they are most needed. Such interventions can enhance self-awareness, foster resilience, and promote adaptive coping mechanisms [62] to reduce the risk of burnout and promote overall well-being in the workplace.

Because burnout is better conceptualized as the end of a continuum between rewarding and overwhelming work experiences rather than a discrete state [55], just-in-time interventions, or EMIs, might be especially useful in preventing negative outcomes associated with burnout. The integration of EMAs can aid in accurately measuring and understanding burnout dynamics, while EMIs offer a practical and proactive approach to prevent and address burnout effectively. Using these innovative technologies together could ultimately help promote more sustainable and supportive work environments, benefiting both employees and organizations alike.

In Table 1, we present examples of the scales and stand-alone questions that have been utilized for EMAs.

Table 1. Examples of the scales and stand-alone questions utilized for ecological momentary assessments (EMAs).

Construct	Scales Used	Stand-Alone Questions Used
Stress & Resilience	• Perceived Stress Scale (PSS; [64]) • Brief Resilience Scale (BRS; [33])	• *Rate your stress levels from 1 (not at all stressed) to 5 (extremely stressed)* [78]

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	• Connor-Davidson Resilience Scale (CD-RISC-10; [65])	• *How well are you coping with the challenges you're currently facing?* [67] • *Pick the image that best captures how stressed you feel right now.* [79]
Well-Being & Happiness	• Satisfaction with Life Scale (SwLS; [66]) • WHO-5 Well-being Index [67]	• *All things considered, how satisfied are you with your life as a whole today?* [80] • *How happy are you right now, on a scale from 0 (not at all) to 10 (completely)?* [81]
Mood & Affect	• Positive and Negative Affect Schedule (PANAS; [68]) • Self-Assessment Manikin (SAM; [69]) • Profile of Mood States (POMS; [70])	• *Rate your mood from 1 to 5 for the following: happy, angry, sad, stressed, worried.* [67] • *Pick the image that best captures your mood right now.* [79] • *How positive do you feel right now (cheerful, enthusiastic, awake, calm, relaxed)?* [82] • *How negative do you feel right now (irritated, bored, nervous/stressed, distressed, depressed)?* [82]
Social Safety & Loneliness	• Goldsmith Social Support Scale [71] • UCLA 3-item Loneliness Scale [72]	• *"At the time of the prompt, were you having any social interaction?"* [44] • *"Since the last alarm, how many times did you socialize with someone else (e.g., spent more than 5 min talking or communicating with someone else)?"* [43]
Energy & Arousal	• Multidimensional Fatigue Inventory (MFI; [73]) • Subjective Vitality Scale [70]	• *Rate your current energy level from 1 (no fatigue) to 10 (worst fatigue)* [83] • *People often describe how they feel right now referring to the metaphor of a battery ranging from exhausted to full of energy. Please indicate which of the following battery icons describes your current state best.* (pictorial scale; [70])
Present-Focus & Mindfulness	• Five Factor Mindfulness Questionnaire- Short Form (FFMQ-SF; [74]) • Cognitive Affective Mindfulness Scale-Revised (CAMS-R; [75])	• *"Which of the following would best characterize these thoughts?" (past-focused, present-focused, future-focused)* [84]
Burnout	• Maslach Burnout Inventory (MBI; [76]) • Oldenburg Burnout Inventory (OLBI; [77])	• *At this point in time, how emotionally exhausted are you from your day?* [13] • *How accomplished do you feel in your work at this moment?* [13]

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Recommendations, Limitations, and Future Directions

As researchers have become increasingly aware that dynamic psychological states, such as acute stress and mood, and discrete experiences impact well-being and health, it is now clear just how important it is to assess these processes using methods that complement their natural dynamics. EMAs accomplish this by combining the ecological validity of real-time assessments in participant's natural environments with the flexibility to schedule data collection as frequently as necessary to capture the temporal dynamics of variables of interest (e.g., several times per week to several times per day). This flexibility enables researchers to design well-powered studies with many participants simultaneously experiencing the same event (e.g., the transition to college, the start of an athletic season, a culturally-significant holiday) that would otherwise be logistically impossible to conduct at scale using tradition lab visits. To aid readers in adopting EMAs approach in their own research, we conclude with some general recommendations/future directions and limitations.

First, existing, non-EMA datasets can be leveraged to explore whether higher temporal-resolution is necessary to reflect a process of interest (e.g., if the temporal stability or retest reliability is low, if standard data collection timescales do not reflect optimal time lags between variables of interest; [85]). Second, researchers interested in EMA should explore different EMA-style designs to consider which would be ideal for their specific research questions. Depending on the process of interest, it might be best assessed using multiple assessments per day EMA, daily EMA, daily diary studies, or measurement burst designs, which combine EMA with longer-term follow-up durations. Third, researchers should brainstorm other complementary methodologies to include in their EMA studies, such as wearable technologies, common stressor designs, geolocation, text-message mining, and multi-omics approaches [86]. Fourth, optimal use of high temporal density data requires complementary statistical techniques. Although a full review of analytic options is outside the scope of this review (see [87] for a broad introduction to techniques tailored to EMA data), we would like to particularly emphasize the potential of dynamic structural equation modeling due to its flexibility (see [88-90]). Additionally, data with at least 60 observations per individual is well-suited for group iterative multiple model estimation (GIMME, [91], which provides information on both group-level and individual-level time series. Fifth, future stress research should consider combining "common stressor" designs—in which all participants experience the same stressful, naturally-occurring event (e.g., job interview, major life transition, auditions)— with EMAs to evaluate effects of interest during ecologically-valid (i.e., not laboratory task-induced) stress. Finally, for the health-focused research reviewed above, results observed in non-clinical samples should be replicated in clinical samples and vice-versa.

As the use of EMA methods continue to gain popularity, is important to emphasize several key limitations of EMA data. First, the frequent assessments introduce burden that must be considered during study design (e.g., length of surveys, survey prompt timing, compensation strategies). Second, the repetitive nature of the surveys can plausibly influence data quality; therefore, participant inattention checks such as screening for items that would be incredibly rarely endorsed by the average participant are a critical tool to ensure data quality [92]. Third, given the frequency of assessment, it is important to check participant compliance with an equally high degree of frequency—lest an extended lack of compliance result in a stretch of unusable data that diminishes or negates the value of the rest of a participant's data. Fourth, given the online nature of many EMA surveys, there are logistical challenges to conducting this research in areas of the world or in populations with limited internet access, which can present a challenge with both collecting EMA data using digital tools as well as with the generalizability of EMA-based research.

Conclusion

In conclusion, EMA methods have the potential to reveal how dynamic fluctuations in psychological states impact stress, well-being, and health. In the present article, we examined their potential by reviewing studies that highlight how assessing aspects of mood, social safety, energy levels, present-focus, and burnout using EMAs can reveal key associations that are missed in more traditional study designs. Assessing these dynamic daily, and within-day fluctuations of these states, can in turn help determine the temporal associations between health-relevant processes, and elucidate the psychological mechanisms through which interventions promote stress-reduction and enhanced well-being. In the future, using EMAs to assess factors that precede health problems will

enable EMIs to be delivered in advance of those health issues developing, thus improving health and well-being. By providing examples of scales and single-item questions used in EMA studies, making concrete recommendations for researchers seeking to employ EMAs in their research designs, and discussing the limitations of EMA methods, we hope to encourage the use of these methods by researchers studying stress, well-being, and health. EMA methods are well-poised to dramatically advance our understanding of the human experience and how such experiences impact human health and wellbeing. To fully realize this potential, EMA research will need to be done carefully, and in a manner that maximizes its scalability, and generalizability, and acceptability to participants.

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