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Understanding stress reports in daily life: a coordinated analysis of factors associated with the frequency of reporting stress

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Abstract

Although stress is a common experience in everyday life, a clear understanding of how often an individual experiences and reports stress is lacking. Notably, there is little information regarding factors that may influence how frequently stress is reported, including which stress dimension is measured (i.e., stressors—did an event happen, subjective stress—how stressed do you feel, conditional stress—how stressful a stressor was) and the temporal features of that assessment (i.e., time of day, day of study, weekday vs. weekend day). The purpose of the present study was to conduct a coordinated analysis of five independent ecological momentary assessment studies

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Conflict of interest Matthew J. Zawadzki, Stacey B. Scott, David M. Almeida, Stephanie T. Lanza, David E. Conroy, Martin J. Sliwinski, Jinhyuk Kim, David Marcusson-Clavertz, Robert S. Stawski, Paige M. Green, Christopher N. Sciamanna, Jillian A. Johnson and Joshua M. Smyth declare that they have no conflicts of interest.

Human and animal rights and Informed consent All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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utilizing varied stress reporting dimensions and temporal features. Results indicated that, within days, stress was reported at different frequencies depending on the stress dimension. Stressors were reported on 15–32% of momentary reports made within a day; across days, the frequency ranged from 42 to 76% of days. Depending on the cutoff, subjective stress was reported more frequently ranging about 8–56% of all moments within days, and 40–90% of days. Likewise, conditional stress ranged from just 3% of moments to 22%, and 11–69% of days. For the temporal features, stress was reported more frequently on weekdays (compared to weekend days) and on days earlier in the study (relative to days later in the study); time of day was inconsistently related to stress reports. In sum, stress report frequency depends in part on how stress is assessed. As such, researchers may wish to measure stress in multiple ways and, in the case of subjective and conditional stress with multiple operational definitions, to thoroughly characterize the frequency of stress reporting.

Keywords

Stress; Stressor; Subjective stress; Ecological momentary assessment; Coordinated analysis

Introduction

Stress in daily life is a ubiquitous experience. Stress is the most common workplace health complaint (Workplace and Health Report, 2016), and workplaces are increasingly attempting to implement interventions to reduce stress among employees (Gladwell & Brown, 2016; Klatt et al., 2017). Stress is also a common symptom driving people to see physicians and therapists (Leger et al., 2016). Results from a national probability sample of adults in the United States assessed for eight consecutive days suggest that at least some stress is reported on nearly 40% of days (Almeida et al., 2002).

Measuring the frequency of stress occurrence is critical for understanding who to target for intervention, and when and how that intervention should be delivered to reduce stress and its negative health effects (Cohen et al., 2007). Yet, emerging work in this area increasingly suggests that our understanding of what stress is, and how to measure stress, may be limited (Epel et al., 2018; Smyth et al., 2018). A recent review calls for a unified model of stress to better harmonize findings across studies and to consider how stress affects health across the lifespan (Epel et al., 2018). Implicit in this domain of work is the idea that different methods used to measure stress could produce different findings. If so, then our current understanding of stress, including its antecedents, its effects, and how to intervene may be misguided. For example, researchers often focus on the causes of stress with the aim to identify possible situations and factors that either aggravate stress or buffer its effects, and then to inform or develop interventions using this information. Recent work in the area of “just-in-time” and related interventions take this logic further, applying interventions at moments of stress (Nahum-Shani et al., 2018; Smyth & Heron, 2016), thus making precise and accurate measurement of stress essential. However, if the items, and/or when those items are delivered, used to assess stress can influence a person’s reporting of stress frequency and intensity, then the results obtained from that research may produce bias that could lead to erroneous conclusions. Interventions may be designed and deployed based on certain

assumptions that could limit the effectiveness of those interventions (e.g., people are equally stressed in the morning or at night, or on a weekday versus a weekend). Alternatively, if the methodological and temporal resolution of when stress is reported can be improved, it may be possible to discover novel associations with stress. Thus, the purpose of this paper is to examine two methodological factors that may be associated with the frequency of reporting stress: the dimension of stress that is measured (e.g., stressor vs. subjective stress) and the timing of those stress assessments (e.g., weekday vs. weekend day). To test whether these factors matter, we will conduct a coordinated analysis of five ecological momentary assessment (EMA) studies that assess frequency of stress across moments within days, as well as aggregating reports to assess day-to-day experiences of stress.

Ecologically valid assessment of stress

Ecologically valid sampling methods were developed in response to the growing recognition that global recall measures of mental process can be problematic (Csikszentmihalyi & Larson, 2014). Primacy and recency biases, for example, might lead to recounting experiences that are heavily influenced by what happened at the initial reporting window or most recently (Smyth & Stone, 2003). Other biases may lead people to remember and weigh particularly impactful or salient events more heavily. In the present paper, we report analyses of studies employing EMA methods that help to circumvent these concerns. EMA involves repeatedly measuring psychological processes in real time as they occur in the natural environment. Such an approach provides measurements that are believed to be more ecologically valid, and that reduce the impact of recall bias by asking people to report on experiences close in time to when they occur (Smyth & Heron, 2012; Smyth et al., 2017). Importantly, research has suggested that measures of daily stress are independently related to distress compared to other more traditional measures, including assessing recent life stressors, levels of chronic stress, and childhood trauma (Wheaton & Montazer, 2010).

Although EMA designs are likely to reduce memory biases, they still may be susceptible to methodological influences as retrospective surveys are. For example, in health-related domains, patients differentially rate the risk of a medical procedure depending on whether survival or death rates are provided (Reyna et al., 2009). With regard to assessing stress, asking participants to reflect on different aspects of the stress process may elicit different information. In terms of stress, individuals may respond differently depending on contextual factors, such as the day of the week (Damaske et al., 2014). In other words, although EMA can limit bias, it still relies on self-report of human interpretation and introspection to collect data. Yet less focus has been paid on considering how EMA measures of stress can be potentially biased (e.g., Epel et al., 2018). Taken together, results of these previous studies suggest the importance of systematically examining methodological factors, including the dimension of stress assessed and temporal features, to determine whether they impact when people report the experience of stress.

Factors associated with frequency of stress reporting

In examining if the frequency of stress reporting is impacted by how it is measured, we consider aspects of both the dimension of stress and temporal features of measurement. For

the dimensions of stress, we consider three possible dimensions that are among the most common ways stress is typically measured in EMA research. (1) The first examines whether a person was exposed to some event that they considered stressful (herein called stressor). This could be asked generally in terms of whether they experienced any event, or specifically in terms of whether they experienced any of a series of potential stressors, such as having an argument or getting stuck in traffic. In measuring reported exposure, this item does not tap specifics about the stressor, including the severity of the experience; rather, it treats all stressors equivalently. (2) Next, we consider people's subjective ratings of how stressed they feel regardless of the explicit event (herein called subjective stress). Importantly, this item does not attempt to understand why someone reports feeling stressed at a particular moment. Subjective stress may be reported due to an event in the environment, due to stressful thoughts, or because of an unknown cause. Subjective stress is important to study as not all stress will be due to recognized and/or reported external events or stressors, yet these subjective appraisals may independently relate to outcomes. (3) Finally, we combine these two approaches and examine people's ratings of how stressful they perceived a stressor event to be (herein called conditional stress). Conditional stress attempts to assess how severe a stressor is, and the extent to which one feels subjectively stressed due to a stressor. Conditional stress is important to study because it does not inherently treat all stressors equivalently, allowing some (even within a stressor 'type') to have more of an impact than others. In sum, these three measures represent fundamental dimensions of the stress experience in daily life, including experienced events (stressor), general appraisals (subjective stress), and appraisals of events (conditional stress).

For temporal features, we consider three features commonly present in EMA (or other short duration intensive longitudinal assessment) studies that track people over time to characterize stress variation within and across days. (1) First, we consider the time of day, reflecting a temporal feature that varies within days. For example, those with a traditional work schedule must prepare for the coming day upon awakening, which may include a commute to work; then when people return home, they may have time, energy, and motivation to engage in physical activity and/ or leisure. Some preliminary work has shown that stress levels vary across the day, with lower levels in the evening compared to midday (Sarker et al., 2016). (2) Next, we test study day (the current number of days a person has been in the study), which is a temporal feature that varies across days. People may go through an adjustment period when completing EMA protocols, at first being vigilant to one's surroundings and experiences but acclimating over time (e.g., Rowan et al., 2007; Shrout et al., 2018). Given this potential for earlier days of measurement to differ from later days, a run-in period is often recommended for EMA studies in which people do the EMA measurement to get used to the protocol but for which the data are not analyzed (Stone & Shiffman, 2002). (3) Finally, we examine day of week, specifically comparing weekdays and weekend days, which is a temporal feature that varies across days. People have different patterns of behavior on weekdays compared to weekend days (Bureau of Labor Statistics, 2014). This pattern may translate to different stress states; for example, employed participants report better moods and more vitality on non-work compared to work days (Damaske et al., 2014; Ryan et al., 2010).

The present study

To explore the importance of stress dimension and temporal features in the rates of reporting stress, the current study presents a coordinated analysis of five EMA studies. Coordinated analysis has the goal of conducting analyses separately across independent studies with some shared, and some systematically varying, characteristics, followed by a comparison of the results (see Hofer & Piccinin, 2009; in contrast to meta-analysis, which has a goal of averaging results across many prior studies to generalize that result to the population). Studies in coordinated analyses typically differ in terms of methods, including utilizing different samples, number of assessment occasions and days, and specific measures, thus precluding (or limiting) meta-analytic and integrated analysis approaches; yet, provided each study assesses the same underlying construct, a coordinated analysis can be conducted to explore commonalities. As such, if results replicate across these independent studies, results can be considered more robust and not due to any idiosyncratic features of one study.

The work presented here is part of the National Institute of Health's Science of Behavior Change program (https://scienceofbehaviorchange.org/). The goal of this NIH program is to take an experimental medicine approach to studying behavior change, with the overarching goal of our research program being the examination of the effects of everyday stress responses on physical activity and sleep patterns in everyday life (Smyth et al., 2018). For this work, we examine five EMA studies that each measured stress, but used different items, and used study designs that varied in terms of study duration (number of days) and density of measurement (number of assessments per day). These studies were strategically sampled as they comprised samples ranging from general community samples to fulltime employed adults to clinic-referred patients with chronic disease. Importantly, these studies are independent projects conducted by different investigators.

For this paper, we first to report on the frequency of stress at any particular moment within days, and then across days with the EMA data aggregated at the day level. In reporting on frequencies within and across days, results will be presented across the differing stress dimensions. Second, we examined how temporal features within days (e.g., time of day) and across days (e.g., study day, weekday versus weekend day) are associated with the frequency of stress reporting. By testing whether the frequency of reporting stress varies as function of what stress dimension is assessed and when, these results have potentially important implications, including informing rigorous study design and facilitating empirically supported approaches to stress intervention work, especially just-in-time and adaptive interventions. For example, this work could be used to develop interventions to disrupt the bidirectional stress and physical activity link, either by encouraging individuals to exercise as a way to buffer against future stress that typically occurs for a person in a particular time and environment, or to engage in physical activity after a stressor to relieve its negative effects (Stults-Kolehmainen & Sinha, 2014).

Method

These coordinated analyses drew from five EMA studies. See Table 1 for a general overview of sample characteristics and study designs. The Effects of Stress on Cognitive Aging,

Physiology, and Emotions (ESCAPE) study examined whether repetitive thinking helps explain how stressors affect cognitive health over time (for details see Scott et al., 2015). The Stress and Working Memory (SAWM) study examined relationships between stress and personality, health status, and working memory (for details see Mogle et al., 2019). A third study—the Stress, Health, and Daily Experiences (SHADE)—examined how daily experiences relate to health and well-being among patients with asthma or rheumatoid arthritis (for details see Smyth et al., 2014). A fourth study—Work and Daily Life (WDL)—examined how workplace stress is associated with health and well-being among full-time employed adults (for details see Smyth et al., 2016). Finally, the North Texas Heart Study (NTHS) examined social vigilance as a predictor of cardiovascular disease (for details see Ruiz et al., 2017).

Samples

ESCAPE

Participants were recruited using systematic probability sampling of New York City Registered Voter Lists for the zip code 10475, an area of Bronx, NY. Exclusion criteria include being younger than 25 or over the age of 65, not ambulatory, not fluent in English, with a visual impairment, and not a resident of Bronx County. Participants (n = 241) ranged in age from 25 to 65 years (M = 46.8 SD = 10.9); women made up 66.4% of the sample. The sample was diverse in terms of racial and ethnic identity: 9.1% identified as Non-Hispanic White, 63.1% as Non-Hispanic Black, 17.8% as Hispanic White, 5.8% as Hispanic Black, . 4% as Asian, and 3.7% as Other.

SAWM

Participants were recruited from advertisements and flyers in a city in the Northeast U.S. Exclusion criteria consisted of the following: younger than 18 years of age or older than 80; being unable to operate a palm-top computer; and having a major cognitive impairment. Participants (n = 172) ranged in age from 20 to 79 years (M = 49.5, SD = 16.9); women made up 51.1% of the sample. More than half (57.9%) of the sample identified as Non-Hispanic White, 31.6% as Non-Hispanic Black, 3.5% as Hispanic Black, and 7.0% as other race or ethnicity.

SHADE

Participants were recruited via print media (e.g., flyers) and television and radio advertisements in a city in the Northeast U.S. for a study examining how daily experiences relate to the health and well-being of individuals diagnosed with chronic illness. Participants (n = 128) with a physician-confirmed diagnosis of RA (n = 97) or asthma (n = 31) completed the study. Of the total sample, 117 participants provided EMA data. Participants had a mean age of 44.2 (SD = 14.2) and were predominantly Caucasian (84%) and female (73%). Exclusion criteria consisted of the following: younger than 18 years of age; no clinically verified diagnosis of rheumatoid arthritis or asthma; current drug or alcohol abuse problems; receiving emergency room treatment (other than minor injury), having a medication or other treatment change, or receiving a diagnosis of a mental illness within the prior 3 months; or being unable to complete the EMA protocol (e.g., due to poor eyesight).

WDL

Participants (n = 122) were recruited in a city in the Northeast U.S. for a study measuring work parameters and health. Participants had a mean age of 41.2 (SD = 11.6) and were predominantly Caucasian (76.1%) and female (74.5%). Exclusion criteria consisted of the following: younger than 18 years of age; not currently employed Monday through Friday with regular working hours between 6:00 a.m. and 7:00 p.m.; employed on weekends; unable to come to the research laboratory on a Wednesday evening and the following Monday; not fluent in English; pregnant; and having a psychiatric therapy or drug treatment change within the prior 3 months. Of the total sample, 112 participants provided EMA data.

NTHS

A diverse community sample from the North Texas area was recruited through advertisements in local newspapers, flyers, community and university websites, and hospital postings. Participants (n = 300) were sampled as stratified by gender within age and race/ethnicity resulting in the following demographics: 150 men, 150 women; aged 21–70 (M = 42.4, SD = 12.8); 60% non-Hispanic Whites, 15% non-Hispanic Blacks, and 19% Hispanic/Latino/a. Exclusion criteria consisted of the following: unable to give informed consent, having a previous history of myocardial infarction, pregnancy within the past 12 months, and/or being a night shift worker.

Procedure

Across all studies, participants were initially screened by phone for eligibility and then set up an appointment for an initial session. At these initial sessions, participants provided informed consent and completed additional baseline questionnaires that are not relevant to the present study (see study-specific references for additional information on such measures).

ESCAPE

The initial session was completed in a research office. Participants were trained on how to use the provided smartphone to complete the EMAs. For the ensuing 16 consecutive days, of which the first two were a run-in period and next 14 were used for data analyses, participants completed five measurements a day with measurements occurring between two and 3 h apart. A maximum of 70 assessments per person was possible; participants averaged 57.9 (SD = 14.5; 82.7%) assessments. At the end of the fourteenth day participants returned the smartphones to the research office, completed some additional measures, and were debriefed.

SAWM

The initial session was completed in a laboratory setting. Participants were trained on how to use the provided palmtop computer to complete the EMAs. For the ensuing nine consecutive days, of which the first two were a run-in period and next seven were used for data analyses, participants completed five measurements a day with measurements occurring between 2 and 3 h apart. A maximum of 35 assessments per person was possible; participants averaged

31.7 (*SD* = 6.5; 90.6% of total possible). At the end of the seventh day participants returned the smartphones to the lab, completed some additional measures, and were debriefed.

SHADE

The initial session was completed in a laboratory setting. Participants were trained on how to use the provided palmtop computer to complete the EMAs. For the ensuing seven consecutive days, participants completed five measurements per day with measurements occurring randomly within roughly 3-h intervals excluding the first and last 15 min of each interval. A maximum of 35 assessments per person was possible; participants averaged 26.1 (*SD* = 10.3; 74.6% of total possible). At the end of the seventh day participants returned the smartphones to the research office, completed some additional measures, and were debriefed.

WDL

The initial session was completed in a laboratory setting. Participants were trained on how to use the provided palmtop computer to complete the EMAs. For the ensuing three consecutive days (Thursday to Saturday), participants completed 6 measurements a day with measurements occurring randomly within roughly two and a half hour intervals excluding the first and last 15 min of each interval. A maximum of 18 assessments per person was possible; participants averaged 17.3 (*SD* = 1.2; 95.6% of total possible). At the end of the third day participants returned the EMA devices, completed some additional measures, and were debriefed.

NTHS

The initial session was completed in a community vascular medicine clinic on a Thursday morning; this visit also included a brief physical exam, completing a personal and family medical history, and providing a fasting blood draw. Participants were subsequently trained on how to use the provided cellphone to complete the EMAs. For the ensuing two consecutive days, participants completed an EMA in 45-min intervals with measurements occurring randomly within each interval. Due to differing study start times and sleep cycles each participant could complete a different number of assessments; participants averaged 27.2 assessments (*SD* = 8.2; 85% of likely possible). At the end of the second day participants returned the smartphones, completed some additional measures, and were debriefed.

Materials

See Table 2 for specific questionnaire items and scale endpoints for all items across studies relevant to the present paper.

ESCAPE

Participants indicated whether anything stressful occurred since the last survey (stressor) and how unpleasant the stressor was (conditional stress).

SAWM

Participants indicated whether anything stressful occurred since the last survey (stressor) and how unpleasant the stressor was when it happened (conditional stress).

SHADE

Participants indicated whether anything stressful occurred since the last prompt (stressor) and how stressful the stressor was (conditional stress).

WDL

Participants indicated whether any of a series of hassles had occurred since the last prompt (stressor), and how stressed they were at the time of the prompt (subjective stress).

NTHS

Participants indicated whether anything stressful occurred since the last prompt (stressor), how stressed they have been since the last measurement (subjective stress), and how stressful the stressor was (conditional stress).

Analytic plan for coordinated analysis

To examine the frequency of stress reporting, binary indicators were coded to reflect whether stress was present or not at any moment (0 indicated no stress, 1 indicated stress). For stressors, a 1 was coded if a participant affirmatively reported something stressful occurred in general, or if they reported any hassles from a provided list.

To extend our approach of evaluating if stress was reported, and because it is often unclear what value of a continuous stress scale at a particular moment or day indicates the affirmative presence of stress, we recoded subjective and conditional stress into binary variables. We acknowledge that dichotomizing subjective and conditional stress can result in the loss of some information and statistical power (MacCallum et al., 2002); however, it is important to highlight that the dichotomizing process is consistent with an experimental medicine approach that often requires a clear cutoff value to trigger an intervention or treatment option (Budczies et al., 2012). Also, the range of the scales across items and studies were different, thus making direct comparisons more difficult. The cutoff allows an easier understanding of when the results across studies converged or not.

To respect the complexity of this dichotomization process, we constructed three different indicators in line with previous theory and research (e.g., DeCoster et al., 2009). These approaches vary in the underlying assumptions (e.g., as to what they reflect) and may also serve as an empirical example for future research on potential ways to dichotomize stress reports if necessary (e.g., a cutoff value is needed). (1) An “any stress” measure was calculated in which the lowest value of the scale was coded as a 0 (the anchor for the lowest value was always not at all stressful) and all other values were coded as 1. Any stress thus takes an all-or-nothing approach to understanding subjective and conditional stress. Yet, this threshold may be too low as experiences close to zero are treated similarly as experiences at the other extreme. Thus, the subsequent alternative definitions calculated were an attempt to

capture more moderate to highly stressful experiences. (2) A “midpoint” measure was calculated in which values below the midpoint of the scale were coded as zero and all values equal to and above the midpoint were coded as 1 (e.g., on a 0–100 scale, values 0–49 were coded as no stress and values 50–100 were coded as stress). This measure attempts to assess how frequently stress levels were reported to be high by using a common criterion across all participants—the item’s scale. By selecting the midpoint, this ensures that more subjectively and conditionally stressful moments are reported. Yet, the accuracy of this definition is predicated upon all respondents using the item’s scale equivalently and exhibiting similar variance in using the scale. (3) An “above personal norm” measure was calculated in which a standard deviation (SD) for each participant was calculated, and then all values that were less than one SD above the mean for that person were coded as 0 and values one SD or greater above the mean were coded as 1. In this way, the threshold is now centered to each person’s own mean and identifies stressor moments as ones that are higher than normal *for that person only* (thus obviating the assumption of the midpoint approach described above). One SD was chosen because using this threshold should ensure sufficient variability on average within participants (~ 16% of assessments as stress moments). Also, this approach creates personalized thresholds that may be more meaningful to an individual as their own typical levels of subjective and conditional stress are taken into account. Finally, a one SD cutoff limits the likelihood of an impossible criterion for those participants who report higher levels of subjective and conditional stress on average. Together, these three ways of coding subjective and conditional stress allow a testing of a range from modest to more severe stress experiences.

The frequency of stress was examined across three temporal features. First, within days, we tested whether time of day influenced the frequency of stress reporting. Time was coded based on the hour of assessment, ignoring minutes, using a military format (e.g., a measurement at 9:23 pm was coded as 21), starting at 0 for midnight. Second, across days, a consecutive count of the study day starting at one was used to examine whether the frequency of stress reporting differed across study day. Third, across days, we coded whether the study day occurred on a weekday (Monday to Friday) or weekend day (Saturday or Sunday) and tested the effect on the frequency of stress reporting.

Results first report the frequency of stress across study and by stress dimension. For the analyses within days, the percentages represent the frequency that stress was reported at any one particular moment (i.e., at each beep) across all available data from all participants. For the analyses across day, the percentages represent the frequency that was reported on any one particular day across all available data from all participants. For these analyses across days, data were aggregated from the momentary reports to day specific summaries. Within each day, if at any moment a condition was met in which stress was coded as being present, then that day was coded as a stress day.

Finally, analyses were conducted to examine temporal features. First, logistic regressions were conducted using PROC GLIMMIX in SAS. The temporal features of study hour (within days), study day (across days), and weekday versus weekend day (across days) were included as predictors of the likelihood of stress in separate models. For the analyses within days, two random intercepts were specified controlling for nesting at the subject level and

day level (days within subjects). For the across-day analyses, a random intercept was specified controlling for nesting at the subject level. For the time of day and study day analyses, time-varying effect modeling (TVEM) also was conducted to investigate possible non-linear time trends. This approach estimates regression coefficients (corresponding to the estimated rates of stress and the associations between predictors and momentary report of a stress) as flexible functions across continuous time. This allows us to visualize the time trends in regression coefficients and the corresponding time-varying confidence intervals for each coefficient function (TVEM SAS Macro, 2015). The p-spline method was used, with an initial number of knots, or splitting points, of 5 specified for each coefficient function based on prior work (Li et al., 2015).

Results

Frequency of momentary stress reports

We examined the frequency of occasions in which people reported stress (moment level) by each stress dimension. Results displayed in the top portion of Table 3 indicates that the frequency of stress reporting varied by stress dimension. Stressors reflect whether a person reported exposure to a stressful event at a particular moment. Across the datasets, stressors were reported between 14.7 and 31.7% of observed occasions (M = 20.4, SD = 7.1). Next, subjective stress assessed whether a person felt stressed at a particular moment regardless of what may have occurred in one's environment. In accordance with our different definitions, rates of reporting varied. Any stress—the all-or- nothing approach—was reported most frequently (46.2–56.4%). Midpoint—the measure of if one reports a stressfulness rating at or above the midpoint of the scale—was less frequent than any stress (19.9–24.7%). Above person norm—that counted stress if one's stressfulness rating was one standard deviation above one's own mean—was least frequent (8.1–9.9%). Finally, conditional stress assessed whether a person rated an experienced stressor as stressful. Again, frequency of conditional stress depended upon how the variable was defined. Any stress (14.9–21.6%, M = 17.1, SD = 3.2) and midpoint (12.8–15.5%, M = 13.8, SD = 1.2) had similar frequencies as stressors, but above personal norm had lower frequencies (3.0–16.0%, M = 6.6, SD = 6.3).

Next, we tested whether frequencies in stress reporting varied as a function of time of day. As can be seen in the top portion of Table 4, there was a statistically significant linear trend of time in which stress was reported less frequently over the course of the day for two of the five studies: NTHS and WDL. For example, for each additional hour, the odds of reporting a stressor decreased by 3% in both studies. The patterns of effects for time of day on reporting were similar across the other stress measures in these studies. No significant findings were observed for SHADE, SAWM, and ESCAPE. To further investigate the complexity of these time trends, TVEM analyses were conducted. Results are depicted for stressors in Fig. 1, but were similar for the other stress measures. In general, the pattern of results suggested a slightly higher reporting rate in stressors when measurements were in the morning for NTHS and WDL, which diminished across the day; a similar effect is seen in the early evening that drops off by nighttime. SHADE, SAWM, and ESCAPE showed relatively flat profiles.

Frequency of stress across days

This next set of analyses examined the frequency of days in which people reported stress (day level). Each moment was coded as a stress or non-stress moment; then days were coded as a stress day if it contained any moment in which stress occurred (coded separately for each stress measure). First, the extent to which stress was reported across days was examined by stress dimension. As can be seen in the bottom portion of Table 3, the frequency of stress varied by stress dimension. Stressors were reported between 42.3 and 75.6% of days (M = 58.1, SD = 15.7). For subjective stress, rates of reporting were most frequent for any stress (87.2–90.4%), followed by midpoint (54.4–71.7%), and least frequent for above personal norm (39.8–57.8%). For conditional stress, any stress (41.1–72.5%, M = 52.8, SD = 14.7) and midpoint (36.1–8.5%, M = 47.1, SD = 14.8) had similar frequencies as stressors, but above personal norm stress had lower frequencies (11.0–47.6%, M = 27.5, SD = 17.7).

Next, we tested whether stress was more frequently reported on days early in the study compared to the end. As can be seen in the middle portion of Table 4, there was a consistent linear trend of time in all but NTHS (likely attributable to having only 2 days of study). For WDL, SHADE, SAWM, and ESCAPE the trend indicated that daily stress was reported less frequently as the time in the study progressed. For example, each additional day in the study decreased the odds of reporting stressors between 4 and 56%. The pattern of effects were similar across the other stress measures. To ensure that study day did not follow a higher order trend, TVEM analyses were conducted. NTHS and WDL were excluded due to having too few days to analyze (only two and three, respectively). Results are depicted for stressors in Fig. 2, but were similar for the other stress measures. All studies indicated that the frequency of reporting daily stress decreased throughout the first study week. SHADE and SAWM suggested a relatively linear pattern across the seven study days, with SAWM perhaps indicating a steeper decline over the first few days. Results from ESCAPE depicted a quick drop in frequency over the first 3 days that slowly declined for the rest of the study period of 14 days.

Finally, we tested whether the frequency of daily stress reporting differed on weekdays compared to weekend days. NTHS was excluded from this analysis as all data was collected on weekdays. As can be seen in the bottom portion of Table 4, stress was reported significantly more frequently on weekdays compared to weekend days for WDL, SHADE, and ESCAPE. For example, individuals were between 36 and 72% less likely to report stressors on weekend days compared to weekdays. The pattern of effects were similar across the other stress measures. SAWM demonstrated a similar pattern as the other four studies, but results were not significant.

Discussion

The purpose of this coordinated analysis was to examine the frequency of stress reporting in people's everyday lives using ecologically-valid assessments, and then to test whether stress dimension and temporal factors influence the level of reporting. In general, there was a range of reporting frequencies across studies, with stressors being reported 15–32% of occasions within each day depending on the study. Across days, the frequency of reporting

stressors ranged from about 42–76% of days depending on the study. The highest stressor frequency was achieved in the WDL study in which participants were prompted to report specific hassles compared to the other four studies that had similar frequencies to each other that asked in general whether anything stressful happened. In other words, in addition to which dimension of stress is measured as will be discussed, these results begin to suggest that even variations in the specificity in which questions are posed can influence the frequency of reports. Other factors, such as the sample characteristics, may also play into rates of reporting (discussed more below).

As expected, how the cutoffs were defined influenced the rates of reporting. Subjective stress was most frequent affirmed of the stress dimensions, with 46–56% of moments and 87–90% of days reported as having stress when using the liberal measure that included all moments with any feeling of being stressed (“any stress”). In other words, participants reported at least some degree of stress on about one-half of all assessments, and on nearly every day. Notably, the patterns were largely consistent across samples suggesting that the relative observed rates are likely fundamental. When subjective stress was coded to measure more impactful moments, whether using a common criteria across participants based on the scale midpoint (“midpoint”) or using a personalized within-person value of one standard deviation above of one’s average level (“above personal norm”), stress was reported about 54–72% of days for midpoint and 40–58% of days for above personal norm. Finally, the frequency of any stress and midpoint conditional stress followed a similar pattern as stressors, due to the inherent correlation between event reports and contingent ratings. These results are expected as midpoint and above personal norm place greater restrictions on what counts as stress compared to any stress. Yet, these different ratings have important implications, for example, if one was trying to determine when to deliver a stress reducing intervention. If the goal of an intervention was to act as often as possible with the aim of targeting any instance of stress, then these findings suggest that more specific item wording (e.g., which hassles did you experience versus did anything stressful happen) and a less restrictive cutoff (e.g., any stress versus midpoint) would be more appropriate. If the goal was to tailor an intervention specifically to a person to target only that individual’s more extreme stress moments, the above personal norm approach would be more useful as a triggering value. Determining the appropriate cutoff could also matter if one was attempting to screen individuals for inclusion in a study or for further monitoring. Too liberal a screen (e.g. any stress), for example, may result in too many individuals being included. Finally, if one was to link stress reports to outcomes, it is possible that only a certain type or intensity of stress matters (i.e., a non-linear relationship), and that different thresholds may better reveal these relationships (Cohen et al., 2018). For example, if linking stress to physical activity, it is important to note that engagement in exercise is not likely to occur more than once a day and not on all days over the course of a week (Lutz, Stults-Kolehmainen, & Bartholomew, 2010). Thus, stress would need to be operationalized in a way that captures these daily patterns, which are likely to be different than periods of sedentary behavior that can occur at various points within a day.

The timing of when stress was measured was also important, particularly across days. First, more stress was reported earlier in the study period than later (e.g., on the first versus fourth day). Four studies showed this pattern (WDL, SHADE, SAWM, and ESCAPE); the fifth

study—NTHS—demonstrated no clear trend, likely due to having only 2 days of measurement. The TVEM analyses suggested declines in frequency happened at least over the first 3 days. This pattern of results suggests some possible adjustment to measurement, at least in terms of reporting stress, yet it is unclear the manner in which the adjustment functioned (Shrout et al., 2018). For example, participants may have been primed (either by doing a new task or the training provided) to think about stress and their environments and behavior; an effect that dissipates as participants acclimate to the repeated measurement or better learn how to self-monitor. This possibility would suggest that people were over-sensitized to the reporting stress initially. Yet, the reverse is also possible in which participants may be more accurate initially but then grow desensitized over time thus using shifting thresholds for identifying stress. One way this adjustment has been framed is in terms of reactivity—in which participants respond differently based on the fact of being observed—yet, the evidence for reactivity to EMA is mixed in other domains (for a review, see Barta et al., 2012), and little work has systematically tested possibility desensitization. More research is needed to understand when reactivity or desensitization is present and what kinds of question types are more likely to produce changes in responding over time. Nevertheless, a run-in period may be advisable to help participants become more comfortable with the assessment and to produce more stable assessments. Such an approach has been used with the reporting of disordered eating via EMA among bulimia nervosa patients (Smyth et al., 2007), and use of a run-in or training period is recommended more generally for capturing momentary, self-report data (Stone & Shiffman, 2002). That said, some of the studies which showed these study day effects did have run-in periods (e.g., ESCAPE and SAWM used 2 days of training). Thus, it may be important to have a long enough time period to begin to acquire more stable estimates not due to time. Another potential implication is that when conducting analyses, any analysis linking momentary stress to momentary outcomes might also look at patterns detrended both at the moment (time of day) and day (study day) level, the latter which is less often done.

NTHS did not show the trend of study day, but it only had 2 days of data collection (on Thursdays and Fridays) with high density of measurements per day (i.e., 2–3 times more than other studies). This study also had lower levels of reporting of subjective stress and stressors at any given moment, but higher frequencies when aggregated at the day level. If stress is evenly distributed across the day, then these results would suggest that shorter intervals do not gain an advantage in detecting stress (see discussion of measuring stress count below for considering if stress is not evenly distributed). A final explanation may be that with the high density of assessments participants raise their threshold for what counts as stress. That is, participants may be better able to track past responses and develop an internal baseline for themselves with such frequent assessments and thus self-screen whether stress at the next measurement is different or more severe enough to “count”. More work is needed to examine over what timescale people are best able to provide accurate reports. Moreover, additional research is needed to understand the influence of “mixed” periods in which a stressor and a positive event might both occur.

Second, the day of the week influenced the frequency of stress reporting. Participants reported more stress on weekdays than weekends, in three of the four studies with weekday and weekend assessments (WDL, SHADE, and ESCAPE). This result makes some intuitive

sense, as people tend to work less and engage in more leisure on weekends than weekdays (Bureau of Labor Statistics, 2014). Moreover, people report better moods and less stress when they engage in leisure compared to moments without (e.g., Zawadzki et al., 2015). Indeed, in the present study, the strongest effect of weekday versus weekend day was found in WDL that exclusively sampled working adults with work schedules comprising non-night shift Monday to Friday work. In order to determine whether specific features of work and leisure contexts account for the weekend differences or, if other psychological processes explain this observed pattern, future work may need to explicitly measure when an individual is working, including those who might work from home and work on weekends.

Within days, time of day had a mixed association with stress reports. For two studies—NTHS and WDL—stress was reported less frequently over the course of the day; no pattern was observed in SHADE, SAWM, and ESCAPE. There is some work to suggest that stress levels are lower in mornings and evenings (Sarker et al., 2016), perhaps tied to working schedules as individuals are happier during non-work moments (non-work evenings and weekends; Ryan et al., 2010). As such, these effects may have been most pronounced in these two studies as they comprised only working days (NTHS) or focused exclusively on working adults (WDL). Given these associations, future research in daily life should be explicit in measuring whether an individual is currently employed, and if so, assessing that person's work schedules (i.e., whether one is at work, whether it is a workday), and modeling this information in understanding when individuals experience stress. If these temporal and contextual features are not taken into account, research might run the risk of overestimating the relationship between stress and outcomes that could also be influenced by these temporal and contextual features.

Finally, it is important to consider the samples on which these coordinated analyses were conducted. The greatest levels of stress reported at any moment were by full-time working adults (WDL) and patients with chronic disease (rheumatoid arthritis or asthma; SHADE). Based on these characteristics, these results suggest that certain individuals may be more likely to experience stress, such as the conflict that can arise among working adults due to competing demands between work and home (Grzywacz, 2000). Other factors that may be important to consider are one's age, race, and gender. For example, although not explored in the present analyses, the studies had a wide age range. Prior research has suggested that experiences and perceptions of the world changes as people age, including that older adults are less likely to notice and attend to negative stimuli compared to younger adults (Isaacowitz et al., 2009). Future research should continue to examine how sociodemographic factors impact the experience and reporting of stress.

Limitations and future directions

There are many approaches to measuring the frequency of stress in everyday life. The studies presented in this paper employed EMA strategies that involved multiple assessments close in time to the referent experiences. For the analyses that tested frequency across days, this required an aggregation of the data to determine if it was a stress day or not. An alternative design comes in the form of daily diary in which typically single measurements are taken, such as at the end of the day before bed, that asks a person to recall what the

entire day was like. Many approaches have used daily diary to measure stress. For example, the Daily Inventory of Stressful Events (Almeida et al., 2002) has been developed and employed to assess a range of stressful events and their objective characteristics across the day. Most notably this inventory was employed in the National Study of Daily Experiences finding, for example, that stressful events tend to be reported on about 40% of days (Almeida et al., 2002)—a rate that appears lower than the aggregated data in the five EMA studies presented here. This difference in frequency could represent random variation, sample characteristics, or it might suggest something systematically different between EMA and daily diary, including how the questions are asked and how often. Indeed, studies comparing EMA reports of coping with stress tend to have poor correspondence with daily diaries that asked about coping that was reported to have happened on that day (e.g., coping attempts reported in EMA were not reported at night with daily diary; Stone et al., 1998). Yet in other work, EMA and daily diary showed stronger correspondence when measuring mood terms, such as happiness (Dockray et al., 2010) and fatigue, depression, and anxiety (Kim et al., 2013). Thus, more work is needed to understand if and when EMA and daily diary are capturing similar processes, particularly in relation to different ways of measuring stress. For example, reporting of stressors may show greater correspondence than subjective ratings that may be more likely to change as the stress intensifies or resolves over the course of the day.

Beyond frequency of reporting, a count of how many stressors people experience in a day may be important to consider. Models of chronic stress suggest that the number of stressor exposures are an important component of what makes stress change being acute to being chronic (e.g., McEwen, 1998; Smyth et al., 2013). Moreover, the accumulation or pileup of exposures over time has been proposed as an independent factor associated with poor health behaviors and subsequent health (Smyth et al., 2018). The methods used in the present study were unable to assess this count as the available datasets only asked if someone experienced an event over a given time period, not how often they experienced that event and whether other events also occurred. Moreover, this frequency is confounded with how often and for how long participants were asked to report on their stress. Future work may wish to more directly assess not just affirmative responses to whether an event occurred, but the amount (or number) of stressors one experiences to better test notions of stress pileup.

In addition to the methodology to assess stress, what counts as stress is important to consider as stress is a multifaceted construct (Smyth et al., 2013). For example, subjective stress might constitute a kind of primary appraisal (e.g., How threatening is this event?) but secondary appraisals are also important (e.g., Do I have the resources to cope with this event?) (Lazarus & Folkman, 1984). Also, one’s physiological reaction may represent an important component of the fight-or-flight response to stress (Selye, 1956/1978). Finally, stress can be both due to external events or internal processes, including perseverative cognitions such as rumination and worry (Brosschot et al., 2006; Smyth et al., 2018). These internal processes can produce a similar set of reactions to external, everyday stressors (Ursin & Eriksen, 2004). In the present datasets, a distinction between reported stress due to external events or internal processes was not made. Thus, future work may wish to explore the potential differential effects of externally and internally driven stressors, as well as other components of the stress process.

Finally, when measuring subjective and conditional stress as dichotomous (e.g., to align with a behavioral medicine approach that typically looks for cutoff values), we coded these constructs in multiple ways. The approach of categorizing stress as any non-zero rating may be overly liberal in its inclusion of what counts as stress. Midpoint assessments used the scale as a standard criteria and selected all moments at or above the middle rating, thus requiring more intense moments to count as stress. Yet, midpoint assessments also assumed that participants used the scale the same way. Above personal norm assessments only counted those moments that were one standard deviation above one's average thus restricting stress to only those most personally rated intense experiences. But such an approach may have been too conservative and missed other important stress moments (e.g., by definition, only a small percentage—distributionally 16%—of moments could count). At this point, it is unclear if there is an ideal way to define subjective and conditional stress; thus it is important to choose which operationalization best captures the stated conceptual model and research goals. It should be noted that these definitions are not fully redundant with each other, as correlations (not presented but available upon request) ranged in the moderately strong (i.e., for the relationships between above personal norm and any stress or midpoint assessments) to large (i.e., for the relationship between any stress and midpoint assessments) range. As such, each may hold unique predictive value and/or demonstrate associations with different outcomes.

Conclusion

The present study utilized a coordinated analysis of five independent EMA studies to examine a range of temporal and methodological factors that might influence the frequency of reporting stress. Relying on the coordinated analysis allowed comparisons across these studies to test if results generalize despite variations in samples and other factors across the studies (Hofer & Piccinin, 2009). In general, results indicated that people report stress frequently in life, but with important and consistent differences in that frequency based on how the item is phrased (e.g., subjective stress was reported most frequently), how stress is defined (e.g., any stress and midpoint were more frequent than above personal norm), and when participants reported their stress (e.g., weekdays had more reported stress than weekend days). Results have important implications for researchers looking to precisely and rigorously measure stress in daily life.

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References

Almeida DM, Wethington E, & Kessler RC (2002). The daily inventory of stressful events: An interview-based approach for measuring daily stressors. Assessment, 9, 41–55. [PubMed: 11911234]

Barta WD, Tennen H, & Litt MD (2012). Measurement reactivity in diary research In Mehl MR & Conner TS (Eds.), Handbook of research methods for studying daily life (pp. 108–123). New York, NY: Guilford Press.

Brosschot JF, Gerin W, & Thayer JF (2006). The perseverative cognition hypothesis: A review of worry, prolong stress-related physiological activation, and health. Journal of Psychosomatic Research, 60, 113–124. [PubMed: 16439263]

Budczies J, Klauschen F, Sinn BV, Győrffy B, Schmitt WD, Darb-Esfahani S, et al. (2012). Cutoff Finder: A comprehensive and straightforward Web application enabling rapid biomarker cutoff optimization. PLoS ONE, 7, e51862. [PubMed: 23251644]

Bureau of Labor Statistics. (2014). American time use survey technical note. Bureau of Labor Statistics. https://www.bls.gov/news.release/atus.tn.htm. Accessed 26 Dec 2018.

Cohen S, Janicki-Deverts D, & Miller GE (2007). Psychological stress and disease. Journal of the American Medical Association, 298, 1685–1687. [PubMed: 17925521]

Cohen S, Murphy ML, & Prather AA (2018). Ten surprising facts about stressful life events and disease risk. Annual Review of Psychology, 70, 7.1–7.21.

Csikszentmihalyi M, & Larson R (2014). Validity and reliability of the experience-sampling method In Csikszentmihalyi M (Ed.), Flow and the foundations of positive psychology (pp. 35–54). Amsterdam: Springer.

Damaske S, Smyth JM, & Zawadzki MJ (2014). Has work replaced home as a haven? Re-examining Arlie Hochschild's time bind proposition with objective stress data. Social Science and Medicine, 115, 130–138. [PubMed: 24869785]

DeCoster J, Iselin AMR, & Gallucci M (2009). A conceptual and empirical examination of justifications for dichotomization. Psychological Methods, 14, 349–366. [PubMed: 19968397]

Dockray S, Grant N, Stone AA, Kahneman D, Wardle J, & Steptoe A (2010). A comparison of affect ratings obtained with ecological momentary assessment and the day reconstruction method. Social Indicators Research, 99, 269–283. [PubMed: 21113328]

Epel ES, Crosswell AD, Mayer SE, Prather AA, Slavich GM, Puterman E, et al. (2018). More than a feeling: A unified view of stress measurement for population science. Frontiers in Neuroendocrinology, 49, 146–169. [PubMed: 29551356]

Gladwell V, & Brown DK (2016). Green exercise in the workplace In Barton J, Bragg R, Wood C, & Pretty J (Eds.), Green exercise: Linking nature, health and well-being (pp. 139–149). New York, NY: Routledge.

Grzywacz JG (2000). Work-family spillover and health during midlife: Is managing conflict everything? American Journal of Health Promotion, 14, 236–243. [PubMed: 10915535]

Hofer SM, & Piccinin AM (2009). Integrative data analysis through coordination of measurement and analysis protocol across independent longitudinal studies. Psychological Methods, 14, 150–164. [PubMed: 19485626]

Isaacowitz DM, Allard ES, Murphy NA, & Schlangel M (2009). The time course of age-related preferences toward positive and negative stimuli. Journals of Gerontology: Series B, 64, 188–192.

Kim J, Kikuchi H, & Yamamoto Y (2013). Systematic comparison between ecological momentary assessment and day reconstruction method for fatigue and mood states in healthy adults. British Journal of Health Psychology, 18, 155–167. [PubMed: 23017062]

Klatt M, Norre C, Reader B, Yodice L, & White S (2017). Mindfulness in motion: A mindfulness-based intervention to reduce stress and enhance quality of sleep in Scandinavian employees. Mindfulness, 8, 481–488.

Lazarus RS, & Folkman S (1984). Stress, appraisal, and coping. New York, NY: Springer.

Leger KA, Charles ST, Turiano NA, & Almeida DM (2016). Personality and stressor-related affect. Journal of Personality and Social Psychology, 111, 917–928. [PubMed: 26796984]

Li R, Dziak JJ, Tan X, Huang L, Wagner AT, & Yang J (2015). TVEM (time-varying effect model) SAS macro users' guide (Version 3.1.0). University Park: The Methodology Center, Penn State. Retrieved from http://methodology.psu.edu. Accessed 26 Dec 2018.

Lutz RS, Stults-Kolehmainen MA, & Bartholomew JB (2010). Exercise caution when stressed: Stages of change and the stress-exercise participation relationship. Psychology of Sport and Exercise, 11, 560–567.

MacCallum RC, Zhang S, Preacher KJ, & Rucker DD (2002). On the practice of dichotomization of quantitative variables. Psychological Methods, 7, 19–40. [PubMed: 11928888]

McEwen BS (1998). Stress, adaptation, and disease: Allostasis and allostatic load. Annals of the New York Academy of Sciences, 840, 33–44. [PubMed: 9629234]

Mogle J, Muñoz E, Hill NL, Smyth JM, & Sliwinski MJ (2019). Daily memory lapses in adults: Characterization and influence on affect. Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 74, 59–68.

Nahum-Shani I, Smith SN, Spring BJ, Collins LM, Witkiewitz K, Tewari A, et al. (2018). Just-in-time adaptive interventions (JITAIs) in mobile health: Key components and design principles for ongoing health behavior support. Annals of Behavioral Medicine, 52, 446–462. [PubMed: 27663578]

Reyna VF, Nelson WL, Han PK, & Dieckmann NF (2009). How numeracy influences risk comprehension and medical decision making. Psychological Bulletin, 135, 943–973. [PubMed: 19883143]

Rowan PJ, Cofta-Woerpel L, Mazas CA, Vidrine JI, Reitzel LR, Cinciripini PM, et al. (2007). Evaluating reactivity to ecological momentary assessment during smoking cessation. Experimental and Clinical Psychopharmacology, 15, 382–389. [PubMed: 17696685]

Ruiz JM, Taylor DJ, Uchino BN, Smith TW, Allison M, Ahn C, et al. (2017). Evaluating the longitudinal risk of social vigilance on atherosclerosis: Study protocol for the North Texas Heart Study. British Medical Journal Open, 7, e017345.

Ryan RM, Bernstein JH, & Brown KW (2010). Weekends, work, and well-being: Psychological need satisfactions and day of the week effects on mood, vitality, and physical symptoms. Journal of Social and Clinical Psychology, 29, 95–122.

Sarker H, Tyburski M, Rahman MM, Hovsepian K, Sharmin M, Epstein DH, et al. (2016). Finding significant stress episodes in a discontinuous time series of rapidly varying mobile sensor data In Proceedings of the 2016 CHI conference on human factors in computing systems (pp. 4489–4501). New York, NY: ACM.

Scott SB, Graham-Engeland JE, Engeland CG, Smyth JM, Almeida DM, Katz MJ, et al. (2015). The effects of stress on cognitive aging, physiology and emotion (ESCAPE) project. BMC Psychiatry, 15, 146. [PubMed: 26138700]

Selye H (1956/1978). The stress of life. New York, NY: McGraw Hill.

Shrout PE, Stadler G, Lane SP, McClure MJ, Jackson GL, Clavél FD, et al. (2018). Initial elevation bias in subjective reports. Proceedings of the National Academy of Sciences, 115, E15–E23.

Smyth JM, & Heron KE (2012). Health psychology In Mehl MR & Conner TS (Eds.), Handbook of research methods for studying daily life (pp. 569–584). New York, NY: The Guilford Press.

Smyth J & Heron K (2016). Is providing mobile interventions "just-in-time" helpful? An experimental proof of concept study of just-in-time intervention for stress management In 2016 IEEE Wireless Health (WH) (pp. 1–7). BetheSDa, MD: IEEE.

Smyth JM, Juth V, Ma J, & Sliwinski M (2017). A slice of life: Ecologically valid methods for research on social relationships and health across the life span. Social and Personality Psychology Compass, 2017, e12356.

Smyth JM, Sliwinski MJ, Zawadzki MJ, Scott SB, Conroy DE, Lanza ST, et al. (2018). Everyday stress response targets in the science of behavior change. Behaviour Research and Therapy, 101, 20–29. [PubMed: 29031538]

Smyth JM, & Stone AA (2003). Ecological momentary assessment research in behavioral medicine. Journal of Happiness Studies, 4, 35–52.

Smyth JM, Wonderlich SA, Heron KE, Sliwinski MJ, Crosby RD, Mitchell JE, et al. (2007). Daily and momentary mood and stress are associated with binge eating and vomiting in bulimia nervosa

patients in the natural environment. Journal of Consulting and Clinical Psychology, 75, 629–638. [PubMed: 17663616]

Smyth J, Zawadzki M, & Gerin W (2013). Stress and disease: A structural and functional analysis. Social and Personality Psychology Compass, 7, 217–227.

Smyth JM, Zawadzki MJ, Juth V, & Sciamanna CN (2016). Global life satisfaction predicts ambulatory affect, stress, and cortisol in daily life in working adults. Journal of Behavioral Medicine, 40, 320–331. [PubMed: 27600638]

Smyth JM, Zawadzki MJ, Santuzzi AM, & Filipkowski KB (2014). Examining the effects of perceived social support on momentary mood and symptom reports in asthma and arthritis patients. Psychology & Health, 29, 813–831. [PubMed: 24568534]

Stone AA, Schwartz JE, Neale JM, Shiffman S, Marco CA, Hickcox M, et al. (1998). A comparison of coping assessed by ecological momentary assessment and retrospective recall. Journal of Personality and Social Psychology, 74, 1670–1680. [PubMed: 9654765]

Stone AA, & Shiffman S (2002). Capturing momentary, self-report data: A proposal for reporting guidelines. Annals of Behavioral Medicine, 24, 236–243. [PubMed: 12173681]

Stults-Kolehmainen MA, & Sinha R (2014). The effects of stress on physical activity and exercise. Sports Medicine, 44, 81–121. [PubMed: 24030837]

The Workplace and Health. (2016). The workplace and health. The Robert Wood Johnson Foundation. http://www.rwjf.org/en/library/research/2016/07/the-workplace-and-health.html. Accessed 26 Dec 2018.

TVEM SAS Macro (Version 3.1.0) [Software]. (2015). University Park: The Methodology Center, Penn State. http://methodology.psu.edu. Accessed 26 Dec 2018.

Ursin H, & Eriksen HR (2004). The cognitive activation theory of stress. Psychoneuroendocrinology, 29, 567–592. [PubMed: 15041082]

Wheaton B, & Montazer S (2010). Stressors, stress, and distress In Scheid TL & Brown TN (Eds.), A handbook for the study of mental health: Social contexts, theories, and systems (2nd ed., pp. 171–199). New York, NY: Cambridge University Press.

Zawadzki MJ, Smyth JM, & Costigan HJ (2015). Real-time associations between engaging in leisure and daily health and well-being. Annals of Behavioral Medicine, 49, 605–615. [PubMed: 25724635]

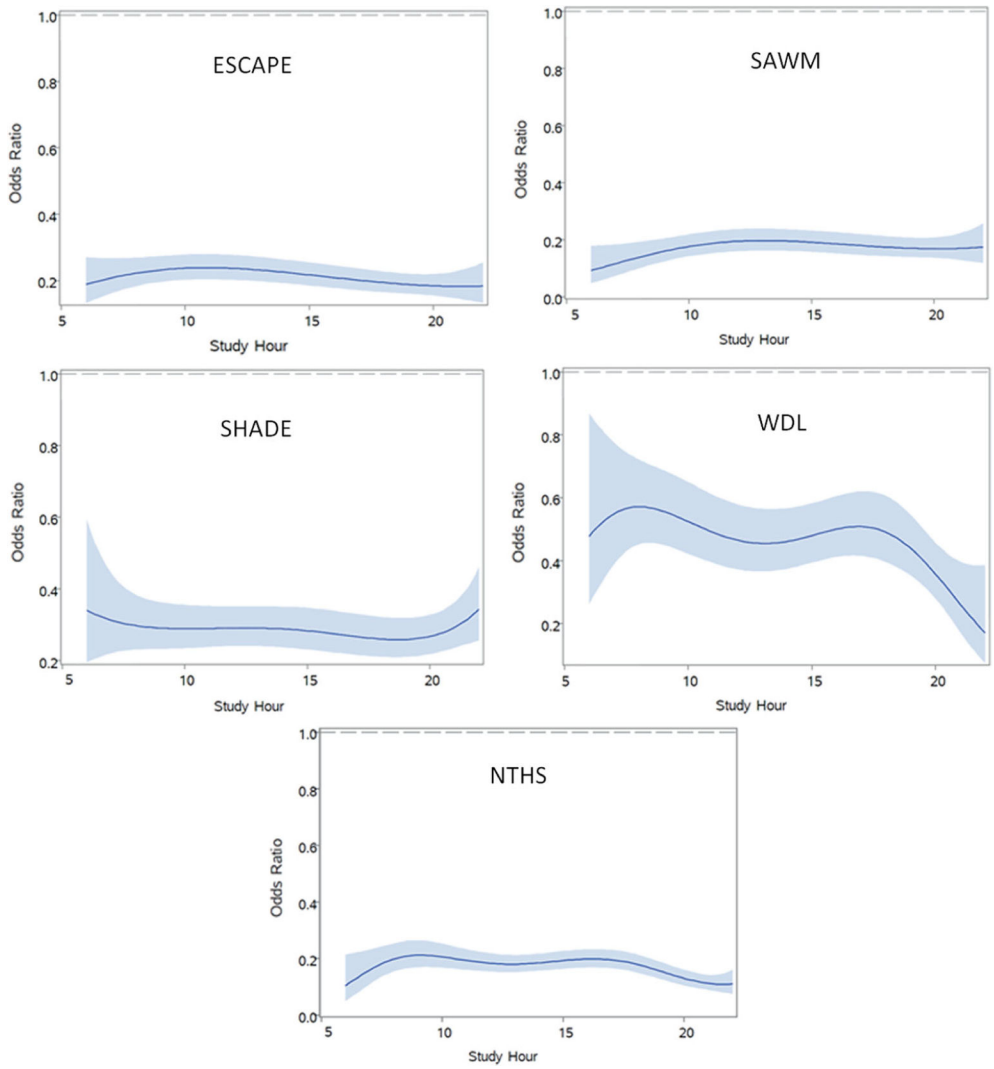

Fig. 1.

Frequency of stressors within moments as a function of time of day. *ESCAPE* Effects of Stress on Cognitive Aging, Physiology, and Emotion, *SAWM* Stress and Working Memory, *SHADE* Stress, Health, and Daily Experiences, *WDL* Work and Daily Life, *NTHS* North Texas Heart Study

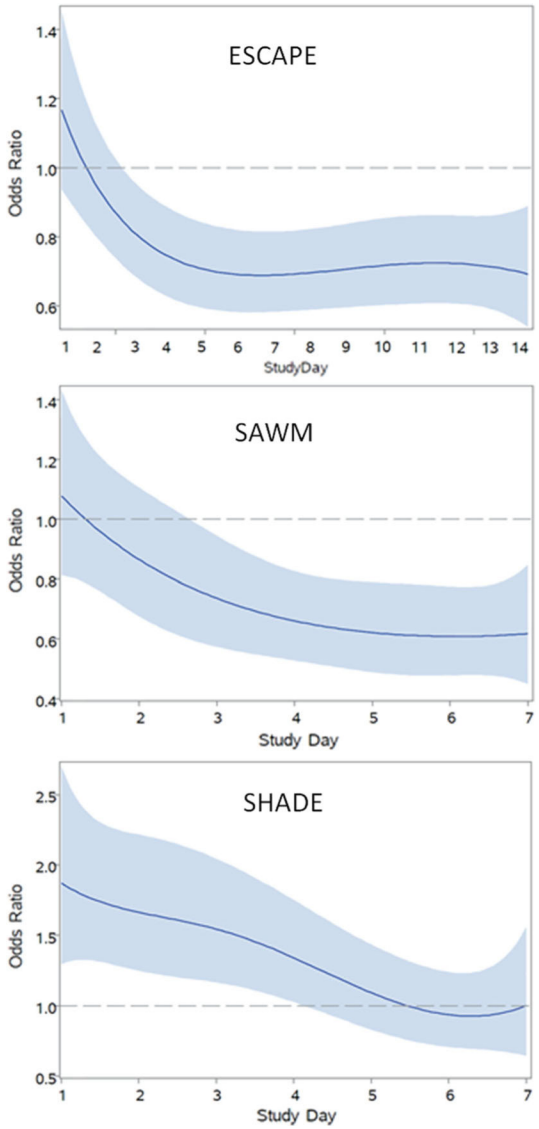

Fig. 2.

Frequency of stressors across days as a function of day of study. *ESCAPE* Effects of Stress on Cognitive Aging, Physiology, and Emotion, *SAWM* Stress and Working Memory, *SHADE* Stress, Health, and Daily Experiences, *WDL* Work and Daily Life, *NTHS* North Texas Heart Study

Table 1

Basic EMA study design and sample characteristics

Study	ESCAPE	SAWM	SHADE	WDL	NTHS
Sample characteristics					
N	241	172	128	122	300
Age					
Range	25–65	20–80	18–80	19–64	21–70
M	46.8	49.5	44.2	41.2	42.4
SD	10.9	16.9	14.2	11.6	12.8
Sample type	Community	Community	Patients	Community	Community
Sampling	Probability	Convenience	Clinic referral	Convenience	Convenience
EMA design					
Duration	14 days	7 days	7 days	3 days	2 days
Beeps/day	5	5	5	6	Every 45 min[a]
Avg. beeps/person	57.9	31.7	26.1	17.3	27.2
Stress measures					
Stressor	✓	✓	✓	✓	✓
Subjective				✓	✓
Conditional	✓	✓	✓		✓

NTHS North Texas Heart Study, *WDL* Work and Daily Life, *SHADE* Stress, Health, and Daily Experiences, *SAWM* Stress and Working Memory, *ESCAPE* Effects of Stress on Cognitive Aging, Physiology, and Emotion

[a]Each participants has different beeps/day due to differing study start times and sleep cycles; EMAs were prompted every 45 min

Table 2

Summary of items used to assess stress frequency

Study	Dimension	Item	Scale
ESCAPE	Stressor	Did anything stressful occur since the last survey? A stressful event is any event, even a minor one, which negatively affected you.	Yes/no
	Conditional	How unpleasant was this event for you?	0 *(not at all)* to 100 *(extremely)*
SAWM	Stressor	Did anything stressful occur since the last assessment?	Yes/no
	Conditional	How unpleasant was this event when it happened?	1 *(not at all)* to 7 *(extremely)*
SHADE	Stressor	Has anything stressful occurred?	Yes/No
	Conditional	How stressful was it?	0 *(not at all)* to 6 *(extremely)*
WDL	Stressor	Since the last prompt, did you experience any of these? (argument; work stress; traffic jam; deadline trouble; paying bills; running late; other)	Check all that apply
	Subjective	At the time of the prompt, how were you feeling? Stressed?	0 *(not at all)* to 6 *(very much)*
NTHS	Stressor	Since the previous cuff inflation, has anything stressful occurred?	Yes/No
	Subjective	In general, how stressed have you been since the previous cuff inflation?	1 *(not at all)* to 7 *(extremely)*
	Conditional	How stressful was it?	1 *(not at all)* to 7 *(extremely)*

ESCAPE Effects of Stress on Cognitive Aging, Physiology, and Emotion, *SAWM* Stress and Working Memory, *SHADE* Stress, Health, and Daily Experiences, *WDL* Work and Daily Life, *NTHS* North Texas Heart Study

Table 3

Frequency of stress at the moment and day level across study and stress dimension

Study	Stressor	Subjective			Conditional		
		Any stress	Midpoint	Above personal norm	Any stress	Midpoint	Above personal norm
Percentage of moments with stress							
ESCAPE	17.7	-	-	-	17.0	13.6	3.0
SAWM	15.1	-	-	-	14.9	12.8	3.4
SHADE	22.7	-	-	-	21.6	15.5	16.0
WDL	31.7	56.4	19.9	9.9	-	-	-
NTHS	14.7	46.2	24.7	8.1	14.7	13.1	4.0
Percentage of days with stress							
ESCAPE	43.2	-	-	-	41.1	36.1	11.0
SAWM	42.3	-	-	-	42.1	38.4	14.3
SHADE	56.8	-	-	-	55.4	45.3	47.6
WDL	75.6	87.2	54.4	39.8	-	-	-
NTHS	72.5	90.4	71.7	57.8	72.5	68.5	36.9

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Table 4

Odds ratios for reported stress corresponding to temporal features, presented across study and stress dimension

Study	Stressor	Subjective			Conditional		
		Any stress	Midpoint	Above personal norm	Any stress	Midpoint	Above personal norm
Time of day (in hours from 0 to 23)							
ESCAPE	.99 [.98, 1.00]	-	-	-	.99 [.98, 1.01]	.99 [.97, 1.00]	.99 [.96, 1.03]
SAWM	1.00 [.98, 1.02]	-	-	-	1.00 [.98, 1.02]	1.01 [.98, 1.03]	**1.05 [1.01, 1.09]**
SHADE	.99 [.98, 1.00]	-	-	-	.99 [.98, 1.01]	.99 [.97, 1.00]	.99 [.96, 1.03]
WDL	**.97 [.94, .99]**	**.96 [.93, .99]**	**.96 [.93, .99]**	**.94 [.91, .98]**	-	-	-
NTHS	**.97 [.95, .99]**	**.97 [.95, .98]**	**.97 [.96, .99]**	.98 [.96, 1.00]	**.97 [.95, .99]**	**.98 [.96, .99]**	.99 [.96, 1.02]
Study day (from 0 and increasing by 1 for each additional day)							
ESCAPE	**.96 [.95, .99]**	-	-	-	**.97 [.95, .99]**	**.96 [.94, .98]**	.99 [.96, 1.02]
SAWM	**.88 [.82, .94]**	-	-	-	**.88 [.82, .94]**	**.90 [.84, .97]**	**.92 [.84, 1.00]**
SHADE	**.89 [.84, .95]**	-	-	-	**.90 [.84, .96]**	**.93 [.87, .99]**	**.93 [.88, .98]**
WDL	**.44 [.31, .64]**	**.34 [.17, .70]**	**.61 [.43, .85]**	**.61 [.46, .80]**	-	-	-
NTHS	**1.64 [1.06, 2.52]**	2.60 [.88, 7.71]	1.23 [.78, 1.93]	1.30 [.92, 1.83]	**1.64 [1.06, 2.52]**	1.44 [.93, 2.22]	**1.45 [1.04, 2.03]**
Weekday (0) vs. Weekend Day (1)							
ESCAPE	**.57 [.47, .69]**	-	-	-	**.59 [.49, .72]**	**.55 [.45, .67]**	**.76 [.58, .99]**
SAWM	.81 [.60, 1.09]	-	-	-	.80 [.59, 1.08]	.78 [.58, 1.07]	.87 [.60, 1.28]
SHADE	**.64 [.45, .89]**	-	-	-	**.63 [.45, .88]**	**.70 [.50, .99]**	.75 [.55, 1.03]
WDL	**.28 [.15, .50]**	**.24 [.08, .74]**	**.31 [.17, .57]**	**.34 [.20, .56]**	-	-	-

Values in bold significant at least at $p < .05$

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