

Perceived Burden and Response Rates of Ecological Momentary Assessment for Daily Stress

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Abstract

Ecological Momentary Assessment (EMA) is widely used to capture stress and related processes in daily life while reducing recall bias. However, frequent and diverse assessments may impose participant burden and affect compliance, particularly in multi-component EMA designs. The present study examined perceived burden and response rates across different EMA components within a 14-day stress-monitoring protocol and investigated how perceived burden and daily stress levels relate to response rate over time.

Forty-seven participants completed a smartphone-based EMA study consisting of prompted morning and evening questionnaires, self-initiated event-contingent stress reports, and conditional prompted 60-minute follow-up assessments. Perceived burden for each component was assessed retrospectively at the end of the study using visual analog scales, and objective response rates were derived from timestamped app logs. Differences in perceived burden were examined using within-subject analyses. Associations between burden, compliance, and daily stress were analyzed using correlation analyses and linear mixed-effects models.

Results showed significant differences in perceived burden across EMA components. Self-initiated stress reports were perceived as most burdensome, followed by the evening questionnaire and follow-up assessments, whereas the brief morning questionnaire was rated as least burdensome. A moderate negative association between perceived burden and response rate was observed only for the morning questionnaire. The relation increased during the second week of participation compared to the first week. Compliance across components declined during the initial days of the study before stabilizing. Higher end-of-day stress levels were associated with increased same-day engagement in self-initiated stress reports and follow-up assessments, but not with next-day compliance.

Overall, the findings indicate that perceived burden varies across EMA components and only partly explains compliance behavior. EMA engagement appears to be dynamically linked to momentary stress rather than delayed effects, underscoring the need to balance scientific goals with participant experience in EMA study design.

Introduction

Stress is a part of modern life, affecting psychological and physiological well-being. Chronic stress has been associated with increased risk of depression, anxiety, and cardiovascular disease (Cohen et al., 2007; Kivimäki & Steptoe, 2017). Repeated daily stress experiences may accumulate and contribute to chronic stress, particularly when recovery opportunities are limited (McEwen, 1998; Almeida, 2005). From both an evolutionary and neurobiological perspective, sustained or repeated activation of stress mechanisms can compromise immune, metabolic, and social functioning, highlighting the value of subtle, real-world measures of stress processes (Slavich, 2020). Additionally, a link between daily stress negative affect and 20-year mortality risk was found (Chiang et al., 2017). Taking this into account not just chronic stress but also prolonged daily stress presents a health risk. Interestingly, it is proven that there are differences between people on how they perceive and adapt to stress. Research using daily assessments indicates that individuals using more adaptive coping strategies experience smaller negative affect in response to similar daily stressors compared to people with less adaptive coping strategies (Koffer et al., 2017; Sun et al., 2023).

But stress and coping strategies are difficult to measure. This is, because traditional retrospective measurements are affected by recall bias, generalization, and reduced ecological validity, yet remain common in stress research. Retrospective assessments are likely to overrepresent salient or recent events and ignore short-term changes or contextual influences

(Ebner-Priemer & Trull, 2009; Shiffman et al., 2008). Additionally, retrospective assessments are susceptible to recall biases, as individuals often reconstruct past experiences considering subsequent events and rely on cognition when estimating the frequency or typical characteristics of stressors. These distortions, together with the influence of current mood states, can substantially reduce the accuracy of retrospective measurements (Yoshiuchi et al., 2008). Due to these limitations the traditional retrospective measurement restricts our understanding of dynamic stress processes as they occur in everyday life. Using only retrospective measure therefore does not give a good and precise estimate on what was really going on in the very moment stress was perceived. Due to its nature, stress processes fluctuate on short timescales, making frequent momentary measurements essential to capture details about the stressor and coping strategy used (Almeida, 2005).

To overcome these limitations, Ecological Momentary Assessment (EMA) has been introduced as a measure to assess psychological and behavioral states in real time, in participants' natural settings (Shiffman et al., 2008). EMA enhances ecological validity and within-person analyses by evaluating experiences in the moment and minimizing errors due to recall (Trull & Ebner-Priemer, 2020). Aggregated momentary stress scores obtained via EMA show meaningful correspondence with traditional retrospective perceived stress measures, demonstrating reliability while also capturing the temporal fluctuations and contextual influences that retrospective measures miss (Murray et al., 2023). Ecological momentary assessment (EMA) has been extensively applied in stress research to capture fluctuations in stress and affect in real time, allowing researchers to examine situational stressors, coping responses, affective dynamics, and contextual influences on daily well-being while minimizing recall bias (Van Roekel et al., 2019). However, as noted by Murray, Yang, et al. (2022, as cited in Murray et al., 2023), considerable

work remains to be done to shed light on momentary stress processes and their effects, including how cumulative momentary stress relates to the long-term development of mental and physical health outcomes. EMA studies commonly distinguish between signal-contingent and event-contingent sampling. Signal-contingent assessment relies on prompts delivered at fixed or random times and is well suited to capturing overall patterns and fluctuations in stress across the day. In contrast, event-contingent assessment requires participants to initiate reports when a predefined event occurs, such as the experience of stress, allowing assessment in close temporal proximity to the stressor and providing more detailed contextual information (Smyth & Stone, 2003). So can coping strategies or environmental aspects that contributed to the perception of the situation be captured. Using this data, similarities and patterns between scenarios and people can be studied.

But also, the downsides of EMA studies need to be considered. EMA studies are demanding. On average, smartphone-based EMA studies take about 13 days and are characterized by at least one or two, up to 12 measurements per day (De Vries et al., 2020). These are usually scheduled (signal-contingent) and prompted automatically. At a specific time, the participant gets a notification and can answer or report on the variables of interest. The assessment can relate to a past interval or to the current moment. Repeated prompts and requests for participation can lead to participant burden and decreased compliance (Smyth & Stone, 2003; Tate et al., 2024). Participant burden in EMA generally refers to the subjective effort, inconvenience, disruption, and attentional or time demands that participants experience as a result of frequent data-collection prompts or self-report requests (Smyth & Stone, 2003). While prompted EMA studies often report relatively high compliance rates typically ranging from 70% to 85% of participants being compliant (van Berkel et al., 2020; Wen et al., 2017) such designs

also risk introducing interruptions that are experienced by participants as intrusive or exhausting. In contrast, event-contingent EMA designs rely on participants to initiate recordings in response to specific events. This can reduce disruption, therefore being less of a burden, but increase concerns regarding reliability and underreporting (Conner & Lehman, 2012; Trull & Ebner-Priemer, 2020). The underreporting can reach up to significant lack of data which is frequently observed in event-contingent EMA studies (Stone et al., 2022).

While EMA is increasingly being utilized, there are surprisingly few studies that have made systematic comparisons of participant burden across different EMA designs. Moreover, while previous studies have examined compliance rates or data quality, there is less insight into participants' views on the perceived burden of different aspects of EMA (van Roekel et al., 2019). Such perceptions are important because perceived burden can influence compliance, engagement, and data validity (Smyth & Stone, 2003). Understanding participant burden is particularly important in stress-focused EMA studies, as capturing within-day fluctuations often requires high assessment frequency. This burden is likely to be higher in signal-contingent EMA designs, where assessments occur at externally imposed times that may interrupt ongoing activities (Shiffman et al., 2008; Smyth & Stone, 2003). In contrast, event-contingent components allow greater flexibility but may introduce different demands, such as the need for continuous self-monitoring. While event-contingent and signal-contingent EMA components have each been widely used, comparatively little research uses different sampling designs within the same study (Wrzus & Neubauer, 2022).

Prior EMA research also indicates that studies lasting more than seven days often show a decline in compliance as novelty wears off and tasks become more burdensome (Ono et al., 2019; Rintala et al., 2019). Beyond assessment of frequency and timing, the content of stress

assessments may contribute to burden. Repeatedly reporting stressful experiences can be emotionally unpleasant and effortful for participants (Smyth & Stone, 2003). One last consideration is that low response rates are unlikely to be random and may be explained by participants' experiences of high stress on a given day (Tate et al., 2024). High stress levels could indicate a conflict in time or cognitive resources and leave the participant unable to respond to the EMA protocol, making event-contingent reports unlikely.

Taken together, these observations highlight a gap in EMA research: While compliance and data quality have been studied extensively, there is limited understanding of how different EMA designs influence perceived burden, and how perceived burden and daily stress relate to actual response rates. The present study addresses this gap by systematically examining perceived burden across signal- and event-contingent EMA components, tracking response rates over time, and investigating the relationship between daily stress and compliance. Understanding these relationships is essential to give recommendations for future designs of EMA studies. The resulting research questions are as follows:

RQ1: How burdensome are different components of a multi-component EMA protocol for daily stress as perceived by participants?

RQ1a: Is participants perceived burden for each EMA component (morning questionnaire, evening questionnaire, self-initiated stress report, follow-up) associated with their response rates for that component?

RQ1b: Does the relationship between perceived burden and response rate differ between the first and second weeks of the study?

RQ2: How does EMA response rate change over the course of the study?

RQ3: Are daily stress levels associated with the EMA response rate on the same day or the following day?

Methods

Participants

Participants were recruited using convenience and snowball sampling strategy and comprised approximately 55 volunteers (mostly students). Inclusion criteria are having a smartphone and the ability to read and understand the study information. Four bachelor students conducted recruitment and study management. All participants provided informed consent prior to the start of data collection, and the study protocol was approved by the University of Twente Ethics Committee, under reference number 252129. Participants received information about the study's aims, procedures, data handling, and researcher contact details during onboarding and intake questionnaire.

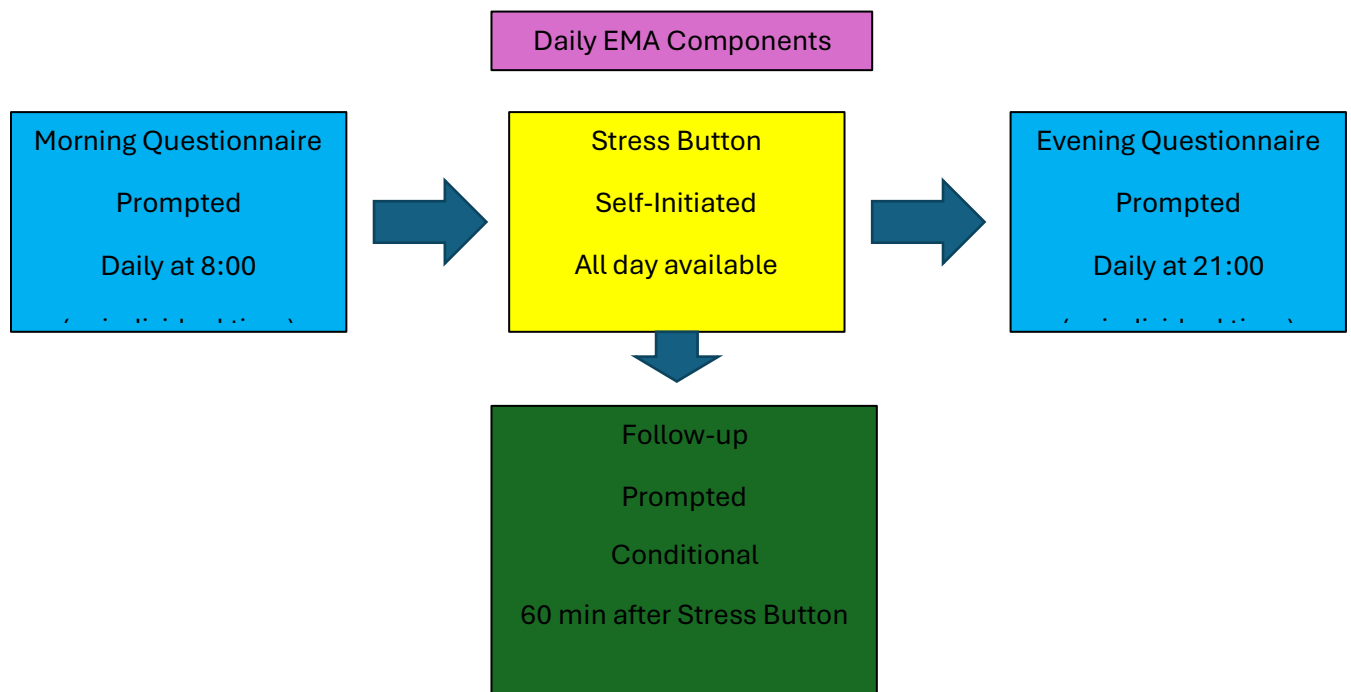
Procedure

The EMA protocol was managed through the m-Path smartphone application and ran for 14 consecutive days. Each morning (available from 08:00 for a 120-minute window) participants completed a brief, prompted sleep item using a VAS ranging from 0-100 answering “How did you sleep?” During the day, event-based measurement was done. When participants felt stressed, they pressed the stress report button, rated current stress on a VAS (0–100), and briefly explained the stressor, for example as an event, a thought, or a feeling. Sixty minutes after each self-initiated stress report the app delivered a conditional follow-up prompt (available for 30 minutes) asking participants to rate momentary stress again (VAS 0–100) and to select one or more coping responses from a multiple-choice list or add an open response if none of the list items fit. The prompted evening questionnaire was available from 21:00 for four hours with

reminders at 60, 120, and 180 minutes. It included a day-level stress rating (VAS 0–100), items about contributors to stress and coping, and an open question inviting a short description of the most stressful situation, followed by a final VAS assessing perceived ability to handle those events (0–100). An overview of this can be seen in Figure 1 below.

Figure 1

Daily EMA Components Overview



An intake questionnaire after app installation included informed consent, brief demographic questions, and onboarding. Immediately after the final daily evening questionnaire on day 14 participants received an end-of-study questionnaire assessing overall satisfaction and perceived burden.

The end-of-study perceived burden measure consisted of four closed items that assessed the perceived component-specific burden. Burden was assessed by four single items asking how burdensome participants found each EMA component (morning questionnaire, self-initiated stress log, 60-minute follow-up and evening questionnaire), each measured on a 0–100 VAS.

Objective app logs recorded for every prompted and self-initiated entry with timestamps, allowing assessment of response rate.

The study team monitored data collection and could contact participants if issues emerged. Participants were provided with contact details of researchers.

Measures

EMA response rate was operationalized using timestamped app logs. Overall response rates were defined as the proportion of scheduled prompts completed by each participant across the study period. The response rate with the self-initiated component was quantified as the proportion of study days on which participants submitted at least one self-initiated stress report. This measure captures whether participants engaged with event-based reporting on a given day, independent of the total number of reports submitted. The follow-up response rate was defined as the proportion of days with at least one follow-up questionnaire completed. This operationalization reflects daily engagement with the conditional follow-up component rather than compliance with all triggered follow-ups.

Component specific burden scores were taken from the retrospective end-of-study VAS (0-100) score. This score was measured just once for every component.

Data Analysis

Data preparation began with exporting timestamped app logs and the end-of-study questionnaires in a confidential manner. App logs were processed to compute participant-level compliance metrics. Data cleaning included removing duplicates, timestamp errors, and participants with extremely low participation for analyses. After data cleaning 47 participants remained.

All analyses will be conducted using R-Studio. First, descriptive statistics will characterize the sample and the EMA usage patterns. Also mean numbers of reports per component, completion rates, as well as distribution of self-initiated logs will be assessed. Other descriptive statistics will include changes in completion rate over the 14 days. Several analyses involved multiple comparisons (e.g., pairwise comparisons between EMA components, correlations across weeks and components, daily stress models). No formal correction for multiple testing was applied in this exploratory study, which increases the risk of type I error. This is a tradeoff to decrease the chance for type 2 errors, as this study is exploratory. Significant results should be interpreted cautiously, and future studies should consider adjustments such as Bonferroni or Holm corrections.

To address the first research question regarding how participants experience different EMA components in terms of perceived burden, component-specific burden VAS scores (morning, self-initiated, follow-up, evening) will be compared within participants. These scores are given through the end of study questionnaire and the one-time retrospective self-report of perceived burden per component. If the four component VAS scores are approximately normally distributed, linear mixed-effects models will be used. If normality is violated, non-parametric within-subject tests (Friedman test) will be applied.

To address research question 1a about how perceived burden corresponds with actual EMA engagement, participant-level component-specific burden ratings will be correlated with response rate metrics. Descriptive statistics will be taken into account. Initial analyses will use Pearson correlations when both variables are approximately normally distributed, and Spearman rank correlations when distributions are skewed. For example, correlations will be computed between overall burden and proportion of days with ≥ 1 self-initiated reports. Also, between

evening burden and evening completion rate, and between follow-up burden and follow-up completion rate. Research question 1b will be similarly assessed, yet the relation will be assessed separately for the first 7 days of participation and day 8 to 14 of participation in the study.

To address research question 2 regarding changes in EMA compliance over time, daily completion rates will be plotted for each component as well as overall daily engagement. Linear mixed-effects models with random intercepts for participants will be used to explore trends in compliance across study days. These models will allow assessment of whether compliance systematically decreases or varies at different time points while accounting for the nested structure of repeated measures within participants. Visualizations of component-specific and overall compliance will be generated to illustrate patterns of engagement, including potential drop-off points.

To address research question 3 regarding the association between daily stress levels and EMA engagement, linear mixed-effects models with random intercepts for participants will be conducted. Two sets of analyses will be run: same-day models assessing whether end-of-day stress levels predict completion on the same day, and lagged models assessing whether end-of-day stress levels predict completion on the following day. This approach allows examination of both immediate and delayed effects of stress on EMA participation.

All continuous predictors in mixed-effects models will be centered within participants to separate within- and between-person effects. Model assumptions, including normality of residuals, homogeneity of variance, and absence of multicollinearity, will be checked prior to interpretation. If violations are observed, robust standard errors or alternative non-parametric approaches will be applied. Model diagnostics will be reported and robust standard errors used if heteroskedasticity is present. Statistical significance will be assessed at $\alpha = .05$, and 95%.

All data processing and analysis scripts will be documented and archived. Reproduction is important, therefore, exclusion, transformation and model specific choices will be transparent and reported. R packages that will be used for primary analyses include psych, lme4, lmerTest and ggplot2 for visualization.

Results

Regarding RQ1 a total of 47 participants were included in the analysis of perceived burden. Four of these participants had missing values for the burden components and were excluded from the analyses. On a 0–100 VAS scale, with higher scores indicating greater perceived burden, the sample reported a mean perceived burden of 12.77 of the morning questionnaire, 33.95 of the evening questionnaire, 37.35 of the self-initiated stress report, and 31.9 of the 60-minute follow-up. Detailed descriptive statistics, including medians and ranges, are presented in Table 1. A Friedman test indicated a significant difference in perceived burden between the components, $\chi^2(3) = 27, p < .001$. Pairwise Wilcoxon signed-rank tests with Holm correction showed that the morning questionnaire was rated as significantly less burdensome than the evening questionnaire ($p = .00078$), self-initiated reports ($p < .001$), and follow-up assessments ($p < .001$). No significant differences were observed between the evening questionnaire and follow-up ($p = .91$), evening and self-initiated reports ($p = .91$), or self-initiated reports and follow-up assessments ($p = .157$).

Table 1

Descriptive Statistics for Perceived Burden Across EMA Components (n = 47)

Component	Mean	Median	Min	1 st Quartile	3 rd Quartile	Max
Morning Q	12.77	5	0	0	20	66
Evening Q	33.95	28	0	10	59.5	90
Self-Report	37.35	30	0	15.5	61.5	90
Follow-Up	31.86	22	0	9	50.5	94

Note. Morning Q = Morning Questionnaire, Evening Q = Evening Questionnaire. Self-initiated and follow-up assessments were reported after the prompted questionnaires for consistency, rather than ordered by mean burden values.

Figure 2 shows the completion rate for the different EMA components in relation to the day of participation in the study. Morning questionnaire completion rate was the highest on day one with 81.8% of participants completing this component on day one. On day four completion rate dropped to 56.8%. Day six had a completion rate of 70.5% before it dropped back to 51.2% on day seven. Around day 9 the completion rate stabilized around 62% before a slight drop to 58.3% on day 14.

Evening completion rate started at 68.2% on day one and increased to 81.8% on day three before it stabilized between 68.2% and 73.7% for the rest of the study, except for day ten with an increase to 78%.

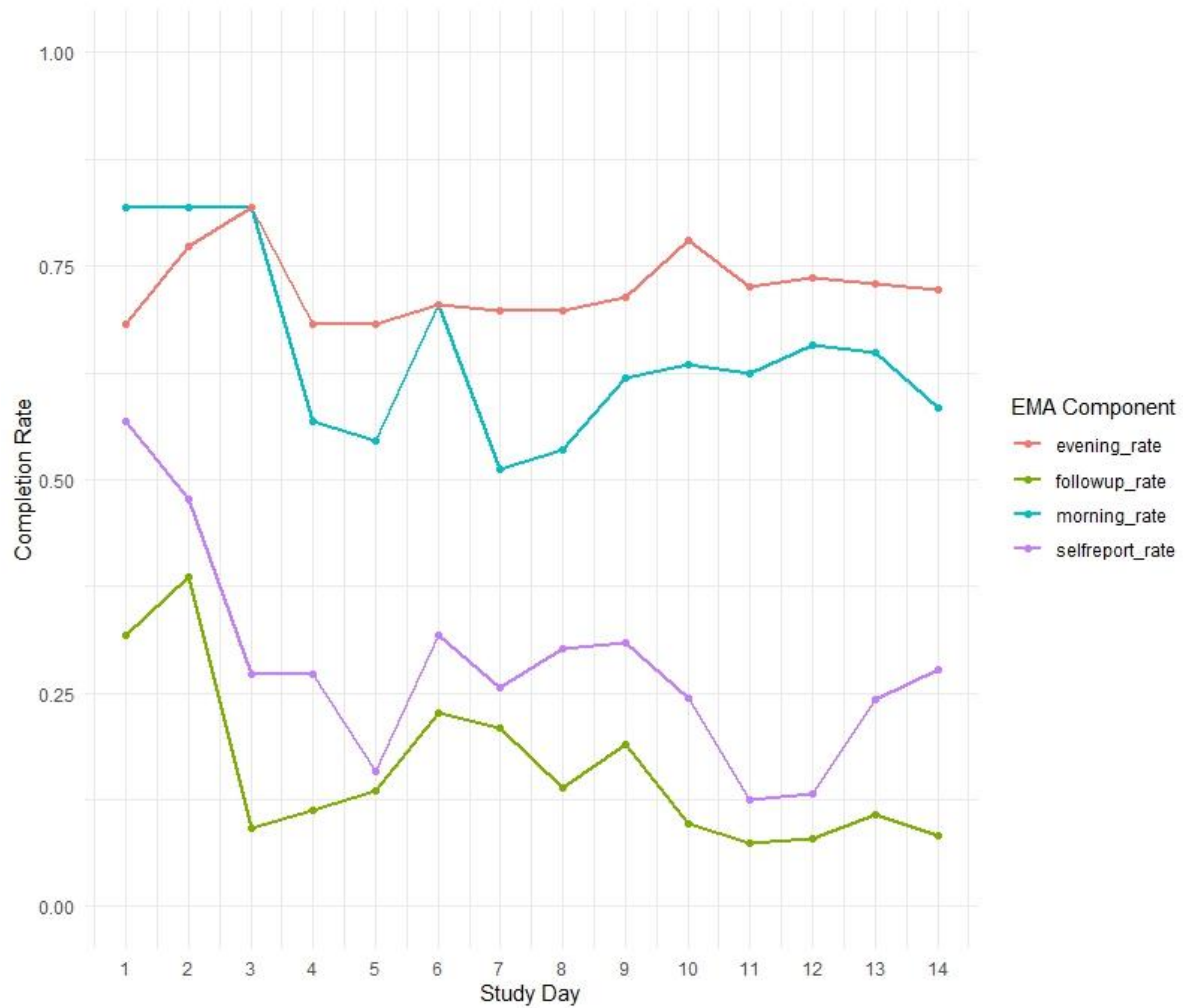
The Self-Report completion rate was measured using days with at least one Self-Report as a day with a completion rate of 100% per participant. So, if 22 out of 44 participants reported stress one time on that day, the Self-report completion rate was 50%. The completion rate was highest at day one with 56.8%. It decreased until day five to 15.9% before it stabilized from day six till day nine at around 30%. Completion rate of the Self-Report decreased to 12.5% on day eleven before going up on day 13 to 24.3% and to 27.8% on day 14.

Follow-Up completion rate was calculated exactly as Self-Report completion rate. It started at 31.8% on day one and increased to 38.6% on day two. On day three, the completion rate decreased to 9% and slowly increased to 22.7% on day six. Day nine had a completion rate of 19% before the completion rate decreased and was below 11% for the rest of the study period.

The evening and morning questionnaire both show moderate to high response rate and have a similar pattern. The self-report and follow-up also show a similar pattern, both with low response rates. The difference in response rate is clear to see, but there are similarities over the study time. So can be seen that response rates of every component dropped around day 3 and 4, before increasing for 2 days followed by another drop in response rate on day 7. Except for the self-report that started to increase every other component, stabilized around day 11.

Figure 2

GGplot of Completion Rate per EMA Component and Study Day



For RQ1a Shapiro-Wilk tests were conducted. Both burden scores and compliance rates showed violations in normality (all $p < .5$). Therefore, Spearman rank-order correlations were computed. Morning burden was significantly negatively correlated with morning completion rate ($\rho = -0.50$, $p = .001$). Evening Burden was significantly correlated with the Follow-Up completion rate ($\rho = -0.320$, $p = .037$), and Self-Report Burden was also significantly correlated with the Follow-Up completion rate ($\rho = -0.354$, $p = .02$). Other relations were not statistically significant.

Table 2

Spearman rank-order correlations between burden score and completion rate

	Morning Burden	Evening Burden	Self-Report Burden	Follow-Up Burden
Morning completion rate	-0.50 (p=0.001)	0.10 (p=0.529)	0.13 (p=0.408)	0.23 (p= 0.141)
Evening completion rate	-0.25 (p=0.104)	-0.13 (p=0.396)	-0.05 (p= 0.776)	-0.03 (p= 0.869)
Self-Report completion rate	-0.16 (p=0.308)	-0.12 (p=0.428)	-0.19 (p= 0.213)	-0.14 (p= 0.368)
Follow-Up completion rate	-0.29 (p=0.058)	-0.32 (p=0.037)	-0.35 (p= 0.020)	-0.22 (p= 0.167)

Note. p-values are unadjusted (interpret with caution due to increased risk of type 1 error).

Spearman rank correlations were conducted to examine the relationship between participant-level end-of-study burden scores and weekly compliance for each EMA component (RQ1b). In Week 1, correlations between perceived burden and compliance were generally small, ranging from $\rho = -.248$ (Evening burden with Follow-Up compliance) to $\rho = .099$. Morning burden was not significantly associated with Morning compliance ($\rho = .099$, $p=.688$),

and Follow-Up burden was not associated with Follow-Up compliance, with the rho coefficient even close to zero ($\rho = .011$).

In Week 2, correlations between all corresponding components increased in magnitude. Morning burden was significantly negatively correlated with Morning compliance ($\rho = -.513$, $p < .001$). Evening burden showed a small negative trend with Evening compliance ($\rho = -.155$). Self-Report burden and Follow-Up burden had small correlations with their corresponding component compliance in Week 2 ($\rho = -.119$ and $\rho = .130$).

To examine RQ3, whether higher evening stress influences daily submissions, linear mixed-effects models with random intercepts for participants were conducted. Evening stress was entered as a daily measure, providing up to 14 observations per participant, and person-centered to reflect deviations from each individual's average stress level. The dependent variable was the number of submissions per day, analyzed separately for Self-Report and Follow-Up. For Self-Reports, there was a small significant positive effect of same-day stress, $b = 0.007$, $SE = 0.001$, $t(429) = 8.48$, $p < .001$, indicating that higher-than-average stress was associated with more Self-Report submissions on the same day. For the following day, the effect was not significant, $b = 0.001$, $SE = 0.001$, $t(394) = 0.52$, $p = .60$, suggesting no effect of stress on next-day submissions.

For Follow-Up submissions a small significant positive effect on the same day, $b = 0.005$, $SE = 0.001$, $t(429) = 5.98$, $p < .001$, and no effect on the following day, $b = -0.00006$, $SE = 0.0008$, $t(394) = -0.07$, $p = .95$ was found.

Morning and Evening components could not be modeled due to very high participation and lack of variability.

Discussion

Summary of Main Findings

The present study evaluated participant burden and response rate in a multi-component EMA protocol assessing daily stress, including prompted morning and evening questionnaires, self-initiated stress reports, and conditional, prompted 60-minute follow-ups. Changes in EMA compliance over time and relation between end-of-day stress levels and compliance were also examined. Taken together, findings indicate that participants perceived the event-contingent self-initiated stress logs as the most burdensome. The prompted Follow-Up and evening questionnaires were also perceived as more burdensome than the prompted morning questionnaire. Perceived burden of the morning questionnaire related moderately to compliance with the morning questionnaire. Interestingly, the effect of this relation increased in the second week.

EMA compliance varied systematically over time and ups and downs were similarly, although on different levels.

Exploratory analyses of the relationship between daily stress levels and EMA engagement revealed that higher-than-average evening stress was associated with increased same-day self-report and follow-up submissions. The effect was small but statistically significant. No effect was observed on next-day compliance.

Perceived Burden Across Components

Participants perceived the self-initiated, event-contingent stress reports as the most burdensome component of the EMA protocol, followed by the prompted evening questionnaire and prompted follow-up. The prompted morning questionnaire was consistently rated as the least burdensome component. These findings suggest that perceived burden varies depending on design features such as event- or signal-contingent design, length, and demands of components.

The low perceived burden of the morning questionnaire may be attributed to how fast it could be answered (1 item only) and integration into daily routines. In contrast, self-initiated stress reports require continuous self-monitoring and decision-making, which may increase cognitive effort (Tate et al., 2024). Similarly, the evening questionnaire and follow-up involved longer or more reflective assessments, which may be experienced as more demanding, particularly at the end of the day. Together, these findings underscore that both structural characteristics and subjective experience shape how burdensome EMA components are perceived.

Relationship Between Burden and Compliance

Associations between perceived burden and objective compliance were limited. A moderate negative relationship was observed only for the morning questionnaire, indicating that participants who perceived this component as more burdensome were less likely to complete it consistently. Importantly, this association was stronger during the second week of the study, suggesting that perceived burden may become more predictive of behavior as the study progresses. One possible explanation is that early in the study, novelty or initial motivation masks the impact of burden on compliance, whereas cumulative exposure to repeated assessments gradually amplifies its influence (Smyth & Stone, 2003; Tate et al., 2024). Although similar trends were observed for other components, these associations did not reach statistical significance. This pattern suggests that perceived burden alone is insufficient to explain compliance behavior and likely interacts with additional factors.

Interesting is, that even though it was rated significantly more burdensome, the evening questionnaire was, except for the first two days of the study, showing same or higher completion rates than the morning questionnaire. This might be because it is easier to miss the morning

questionnaire due to shorter availability. The time was adjusted to fit the participants' sleeping patterns during the onboarding, but changes in schedule for example the weekend might played a role here.

Temporal Patterns of Compliance

Compliance patterns changed systematically over the course of the study. Across EMA components, completion rates were highest during the initial days (except evening questionnaire, however it was still high), declined within the first 4 days, and stabilized around day 11. This shared temporal pattern suggests that changes in compliance reflect general study-level processes, such as adaptation, fatigue, or diminishing novelty effects, rather than characteristics of individual EMA components alone (Ono et al., 2019; Rintala et al., 2019).

End-of-day Stress and Compliance

Exploratory analyses indicated that higher end-of-day stress levels were associated with increased same-day engagement in event-contingent stress reports and also follow-up questionnaires. This effect was small but statistically significant and did not extend to next-day compliance, suggesting that stress primarily influences immediate engagement with EMA components.

One interpretation is that heightened stress increases awareness of stress-related experiences, thereby prompting participants to initiate reports more readily. Alternatively, higher stress may coincide with situations in which reporting is perceived as more relevant or meaningful. The absence of lagged effects indicates that stress does not appear to affect subsequent participation, but rather affects engagement in close temporal proximity to the experience. These findings align with the notion that EMA engagement is dynamically linked to momentary psychological states. Another explanation can be that the compliance is actually

better than one would expect, due to the consideration that the participants might have nothing to report on most of the days. However, a higher correlation between stress and self-reports should be observable when this is the case to increase the likelihood and statistical strength of this perspective.

Limitations and Future Suggestions

Several limitations should be considered when interpreting the findings of this study. First, perceived burden was assessed only once at the end of the 14-day EMA protocol. Although this retrospective assessment provided an overall evaluation of component-specific burden, it does not allow examination of how burden may have changed across the study period. Given that compliance patterns varied over time and that associations between burden and compliance strengthened in the second week, it is plausible that perceived burden also evolved dynamically. Repeated or momentary assessments of burden would allow future studies to better capture fatigue, adaptation, and temporal fluctuations in participant experience.

Second, comparisons between prompted and event-contingent EMA components are difficult. Components differed not only in initiation mode (signal- vs. event-contingent), but also in length, timing, conditionality, and purpose. For example, the follow-up questionnaire was both prompted and conditional on a self-initiated report, complicating direct comparisons of burden and compliance across components. As a result, observed differences cannot be attributed to initiation mode alone, but likely reflect an interaction of multiple design features.

Third, ceiling effects were observed for the morning and evening questionnaires, as well as for some component-specific burden ratings. Limited variability in these measures reduced statistical sensitivity and restricted the ability to detect associations with stress or burden. This limitation is particularly relevant for analyses examining stress compliance relations, as high and

stable completion rates precluded meaningful variability in prompted components. Future research could address this by incorporating more flexible or optional elements within prompted assessments to better capture individual differences in engagement.

Fourth, the study relied exclusively on self-reported stress measures. While EMA self-reports are well suited for capturing subjective stress experiences, they may be influenced by reporting biases and do not provide objective validation. Integrating physiological indicators of stress, such as heart rate variability or cortisol, could complement self-reports and provide a more comprehensive assessment. However, such approaches may also increase intrusiveness and participant burden, highlighting a trade-off that future studies must carefully consider.

Finally, the exploratory nature of several analyses should be acknowledged. No formal correction for multiple comparisons was applied in order to reduce the risk of Type II errors in this exploratory study. Consequently, some statistically significant findings, particularly small effects, should be interpreted cautiously and require replication in confirmatory designs.

Conclusion

This study demonstrates that perceived burden differs systematically across EMA components and that these perceptions are modestly associated with compliance, particularly as study duration increases. Event-contingent self-initiated stress reports were perceived as most burdensome, whereas the brief and predictable prompted morning questionnaire, was experienced as least demanding. However, high completion rates for the evening questionnaire indicate that compliance is influenced by multiple factors beyond perceived burden alone.

Additionally, daily stress showed a small but immediate association with engagement in self-initiated and follow-up assessments. Together, these findings provide evidence-based guidance for optimizing EMA protocols in stress research. Designing participant-friendly

assessments requires balancing scientific objectives with subjective experience, ensuring that EMA remains both methodologically rigorous and feasible for participants in real-world contexts.

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Appendix

Informed Consent

In this study, we want to investigate daily-life stress: how often people experience stress, what the reasons are they feel stressed, and how they deal with it. Understanding stress in daily life is important, because it has important influences on our well-being. We want to investigate daily-life stress using ecological momentary assessment (EMA). EMA is a method with which we ask people to fill out very short questionnaires in their daily life. We want to investigate if we can measure stress this way, and how it is for participants in our study to report on their stress this way.

Participants will receive a smartphone notification in the morning and in the evening for 14 days in a row, asking them to fill in a brief questionnaire. The morning questionnaire will ask participants to rate their sleep. The evening questionnaire will ask participants to reflect on their day and how stressful it was.

If a stressful situation occurs during the day, participants are asked to open the app and fill out an very short questionnaire. 90 minutes after this questionnaire, participants will receive a follow-up questionnaire.

At the end of the two weeks, participants will receive a final questionnaire. Because it is important for us to get a complete picture of daily-life stress, it is crucial that participants fill out the questionnaires as consistently as possible. As a reward, participants can earn up to 2 SONA credits, depending on how many questionnaires they fill in. If they fill in at least 80% of the questionnaires, they will receive 2 SONA credits. In case they fill in less than 80% they don't receive any SONA credits.

The Ethical Committee of the University of Twente approved this study. The data of this study will be used for publications. Participation in this study is entirely voluntary, and participants can withdraw at any time without providing a reason. We believe there are no known risks associated with this research study; however, as with any online related activity the risk of a breach is always possible.

To the best of our ability, participants' answers in this study will remain confidential. Participant data will not be able to be linked to anyone in any way and will only be accessible by the researchers working on this study. All personal data will be coded, encrypted, and stored separately from other types of data.

Questionnaires

Demographics

What is your gender?	Multiple Choice (one) <ul style="list-style-type: none"> - Female - Male - Non-binary/third gender - Prefer not to say
Select your age	Number
What is your country of origin?	Multiple Choice (one) <ul style="list-style-type: none"> - Netherlands - Germany - Other, namely
What is the highest degree or level of school you have completed?	Multiple Choice (one) <ul style="list-style-type: none"> - Lower than high school diploma - High school diploma - Trade and vocational school - Bachelor's degree - Master's degree - PhD - Other
Which of the following categories best describes your employment status?	Multiple choice (one) <ul style="list-style-type: none"> - Employed full time - Employed part time - Student - Student with parttime job - Not employed - Retired - Prefer not to disclose

Baseline

How stressful were the last seven days?	VAS 0-100: Not at all ... very stressful
How stressed are you feeling right now?	VAS 0-100: Not at all ... very stressed
Were there any impactful incidents during the last two weeks?	Multiple Choice <ul style="list-style-type: none"> - No - Yes, namely

Morning Questionnaire (available at 8 o'clock for 120 minutes, reminder after 60 minutes)

Good morning! How did you sleep?	VAS 0-100
----------------------------------	-----------

	Very bad ... very well
Thank you! Remember to tell us if you feel stressed today!	

Stressful situation (self-initiated)

At this moment, I feel stressed	VAS 0-100: Not at all ... very much
What has contributed to your stress? This was a ...	Multiple choice (one) <ul style="list-style-type: none"> - Event (e.g. an argument or having to rush) - Thought (e.g. fretting or worrying) - Feeling (e.g. gloom, irritation, hunger, pain, fatigue)
Thank you! We will check in with you in a bit.	

Follow up to stressful situation (60 minutes after self-initiated, 30 minutes available)

At this moment, I feel stressed	VAS 0-100: Not at all ... very much
What did you do with the stressful event/thought/feeling?	Multiple choice (several) <ul style="list-style-type: none"> - I tried to think of a solution - I worried about it or kept thinking about it - I tried to look at it in a positive way - I tried to accept it - I told someone about it (in-person, via the phone, or social media) - I expressed my feelings about it (e.g., cried or cursed) - I tried to hide my feelings about it - I have tried to distract myself (e.g., by doing something else or to relax) - I tried to calm myself down/to relax - I've engaged in unhealthy behavior (e.g., smoking, overeating) - Otherwise, namely ... - I did not do anything yet, but I am planning to - I did nothing

Evening Questionnaire (available at 9 o'clock for 18 minutes, reminders after 60,120 minutes)

How stressful was your day?	VAS 0-100 Not at all ... very stressful
<i>Follow up (if previous >10)</i> What contributed to your stress? This could be: <ul style="list-style-type: none"> - events (e.g., an argument or having to rush) - thoughts (e.g., worrying or ruminating) - and/or feelings (e.g., sadness, frustration, hunger, pain, fatigue) 	Multiple choice <u>self-learning</u> (several)
<i>Follow up (if first >10)</i> How did you deal with the [ANSWERS PREVIOUS QUESTION] today?	Multiple choice (several): <ul style="list-style-type: none"> • I tried to think of a solution • I worried about it or kept thinking about it • I tried to look at it in a positive way • I tried to accept it • I told someone about it (in-person/ phone/ online) • I have tried to distract myself (e.g., by doing something else) • I tried to calm myself down/to relax • I've engaged in unhealthy behavior (e.g., smoking, overeating) • I expressed my feelings (e.g., cried or cursed) • I made effort to hide my feelings • Otherwise, namely ... • I did nothing
<i>Follow up (if first >10)</i> Briefly describe your day using the stressful moments, why they were stressful, and how you dealt with them.	Open question
I feel I could handle these events, thoughts and/or feelings	VAS 0-100: Strongly disagree ... strongly agree
Thank you, have a good night.	

End Of Study

General	
----------------	--

Overall, I am satisfied with the ease of filling out the scheduled questionnaires (morning and evening) in this study.	Likert Scale: 1-7 Strongly disagree ... strongly agree
Overall, I am satisfied with the amount of time it took to complete the scheduled questionnaires (morning and evening) in this study.	Likert Scale: 1-7 Strongly disagree ... strongly agree
Overall, I am satisfied with the support information (onboarding, contact to researcher) about the scheduled questionnaires (morning and evening).	Likert Scale: 1-7 Strongly disagree ... strongly agree
Overall, I am satisfied with the ease of filling out the self-initiated questionnaires (stressful situations) in this study.	Likert Scale: 1-7 Strongly disagree ... strongly agree
Overall, I am satisfied with the amount of time it took to complete the self-initiated questionnaires (stressful situations) in this study.	Likert Scale: 1-7 Strongly disagree ... strongly agree
Overall, I am satisfied with the support information (onboarding, contact to researcher) about the self-initiated questionnaires (stressful situations).	Likert Scale: 1-7 Strongly disagree ... strongly agree
Compliance	
How did you feel about being asked to self-report any stressful situation? Think of details like: <ul style="list-style-type: none"> - How easy was it to remember this task? - Was it natural or did it feel unusual? - Did you experience any relief after reporting? 	
Do you feel you generally reported stress in the moment it came up?	VAS 0-100 Never ... Always
<i>Follow up (if previous <50):</i> What hold you back from reporting stressful situations?	Multiple choice (several) <ul style="list-style-type: none"> - Another activity - No network connection - Being asleep - Technical problems - Other, namely
What could have facilitated your reporting of stress in the moment it came up?	Multiple choice (several) <ul style="list-style-type: none"> - Reminders during the day - Receive incentives / payments - Receiving feedback on my data at the end of the study - Simple/ shorter questionnaires

	<ul style="list-style-type: none"> - More intuitive application interface - Better introduction at the start of the study - Other, namely:
How feasible do you think it would be for you to consistently follow this procedure for three months?	VAS 0-100 Not at all ... Absolutely feasible
<i>Follow up (if previous <40):</i> What are the main reasons for being sceptic?	Open question
What would facilitate the compliance for a prolonged time?	Multiple choice (several) <ul style="list-style-type: none"> - Reminders during the day - Receive incentives / payments - Receiving feedback on my data at the end of the study - Simple/ shorter questionnaires - More intuitive application interface - Better introduction at the begin of the study - Snooze a reminder to receive another later on Other, namely:
The duration of the study was burdening	Likert 1-7 Not at all - moderate - very
The number of questions was burdening	Likert 1-7 Not at all - moderate - very
The frequency of the assessments felt burdensome	Likert 1-7 Not at all - moderate - very
Overall participating in this study felt burdening	Likert 1-7 Not at all - moderate - very
How burdening was the morning questionnaire?	0-100
How burdening was the self-reported stress log?	0-100
How burdening was the 60min follow-up?	0-100
How burdening was the evening questionnaire?	0-100
Is there anything else about your experience with study that you would like to share?	Open question

AI Statement

AI-assisted tools (ChatGPT, GPT-5) were used to support code generation in R and to facilitate brainstorming during the planning of analyses. All data analysis decisions, interpretation of results, and manuscript writing were performed by the author.

R-Code

packages

```
install.packages("tidyverse") install.packages("readr") install.packages("dplyr")  
install.packages("mpathr")
```

libraries

```
library(tidyverse) library(readr) library(dplyr) library(mpathr) library(tidyr) library(stringr)
```

read files using ;

```
data_raw <- read_mpath( file = "basic_v1.1.csv", meta_data = "meta_v1.1.csv" ) basic <-  
read_delim("basic_v1.1.csv", delim = ";") meta <- read_delim("meta_v1.1.csv", delim = ";")  
skipped <- read_delim("skipped_v1.1.csv", delim = ";")
```

```
rts <- read_delim("rts_v1.1.csv", delim = ";")
```

#extract data

Extract data and meta

```
basicext <- data_raw$data metaext <- data_raw$meta
```

```
str(data_raw)
```

col names

```
names(data_raw) names(meta) names(basic) names(rts) names(skipped)
```

List of potentially relevant variables

```
vars_of_interest <- c(
```

IDs

"connectionId", "alias", "timeStampStart", "timeStampStop", "timeStampSent",
"timeStampScheduled",

Demographics

"Age_sliderNeutralPos", "Gender_multipleChoice_string",
"Country_of_origin_multipleChoice_string", "School_degree_multipleChoice_string",
"Employment_multipleChoice_string",

Stress & Affect

"day_stress_sliderNeutralPos", "stressed_sliderNeutralPos",
"baseline_Stressed_sliderNeutralPos", "stress_gespannen_sliderNeutralPos",
"affect_positive_sliderNeutralPos", "affect_negative_sliderNeutralPos",
"cognitive_sliderNeutralPos", "day_valence_sliderNeutralPos",
"day_stress_line_continuousLine", "Evening_Day_sliderNegPos",

Coping

"coping_multipleChoice_string", "coping_unpl_multipleChoice_string",
"Evening_Coping_multipleChoice_string", "Evening_HandleStress_sliderNegPos",
"Evening_handle_unpleasant_sliderNeutralPos",

Sleep

"Morning_SleepQuality_sliderNegPos", "sleep_sliderNegPos",

Context / Situation

"Evening_stressors_open", "Evening_stressors_multipleChoice_string",
"stressor_b_multipleChoice_string", "stressor_event_multipleChoice_string",

Study evaluation / EoS

"EoS_OverallExperience_sliderNegPos", "EoS_Recommend_sliderNegPos",
"EoS_ClearityOfInstructions_sliderNegPos", "EoS_mPath_sliderNegPos",
"EoS_Burden_Morning_sliderNegPos", "EoS_Burden_SelfReport_sliderNegPos",

```
"EoS_Burden_FollowUp_sliderNegPos", "EoS_Burden_Evening_sliderNegPos",  
"EoS_AnythingElse_open" )
```

checking if variables exist

```
vars_present <- vars_of_interest[vars_of_interest %in% colnames(data_raw)]
```

filtered dataset

```
data_filtered <- data_raw %>% select(all_of(vars_present))
```

```
unique(data_raw$questionListName)
```

```
table(data_raw$questionListName)
```

```
colnames(data_filtered)
```

```
data_filtered$questionListName <- data_raw$questionListName
```

```
#select only questionnaire not reminder
```

```
forms_keep <- c("Morning Questionnaire", "Evening Questionnaire", "Stress_button", "Follow  
up", "End of Study" )
```

```
data_clean <- subset(data_filtered, questionListName %in% forms_keep)
```

```
#timestamps data_clean <- data_clean %>% mutate( timeStampStart =  
as.POSIXct(timeStampStart, origin = "1970-01-01", tz = "Europe/Berlin"), timeStampStop =  
as.POSIXct(timeStampStop, origin = "1970-01-01", tz = "Europe/Berlin"), timeStampSent =  
as.POSIXct(timeStampSent, origin = "1970-01-01", tz = "Europe/Berlin"), timeStampScheduled  
= as.POSIXct(timeStampScheduled, origin = "1970-01-01", tz = "Europe/Berlin") )
```

create date column

```
data_daily0 <- data_clean %>% mutate( date = as.Date(timeStampStart), participantID =  
connectionId # adjust here if needed )
```

```
#check if it worked str(data_daily0[, c("connectionId", "participantID", "timeStampStart",  
"date")])
```

```
#create forms forms_morning <- c("Morning Questionnaire", "Morning") forms_evening <-  
c("Evening Questionnaire", "Evening", "Evening (last)") forms_followup <- c("Follow up")
```

```
forms_stress <- c("Stress_button") forms_reminder <- c("Afternoon Reminder", "Lunch  
Reminder")
```

```
#label questionnaire data_labeled <- data_daily0 %>% mutate( formType =  
case_when( questionListName %in% forms_morning ~ "Morning", questionListName %in%  
forms_evening ~ "Evening", questionListName %in% forms_followup ~ "Followup",  
questionListName %in% forms_stress ~ "StressButton", questionListName %in%  
forms_reminder ~ "Reminder", TRUE ~ "Other" ) ) colnames(data_labeled)
```

check labeling errors

```
table(data_labeled$formType) table(data_labeled$questionListName, data_labeled$formType)
```

unscheduled timestamps (1970.01.01) into n/a

```
data_labeled <- data_labeled %>% mutate( timeStampScheduled = ifelse( timeStampScheduled  
<= as.POSIXct("1970-01-02", tz = "Europe/Berlin"), NA, timeStampScheduled ) )
```

timestamps back to time

```
data_labeled <- data_labeled %>% mutate( timeStampScheduled =  
as.POSIXct( timeStampScheduled, origin = "1970-01-01", tz = "Europe/Berlin" ) )
```

extract burden scores

Step 1: Extract burden scores per participant (once)

```
burden_scores <- data_labeled %>% select(connectionId, EoS_Burden_Morning_sliderNegPos,  
EoS_Burden_Evening_sliderNegPos, EoS_Burden_SelfReport_sliderNegPos,  
EoS_Burden_FollowUp_sliderNegPos) %>% distinct(connectionId, .keep_all = TRUE)
```

what is wrong

```
data_labeled %>% filter(questionListName == "End of Study") %>% select( connectionId,  
questionListName, EoS_Burden_Morning_sliderNegPos, EoS_Burden_Evening_sliderNegPos,  
EoS_Burden_SelfReport_sliderNegPos, EoS_Burden_FollowUp_sliderNegPos ) %>% head(10)
```

fix burden score

```
burden_scores <- data_labeled %>% filter(questionListName == "End of Study") %>%  
select( connectionId, EoS_Burden_Morning_sliderNegPos,  
EoS_Burden_Evening_sliderNegPos, EoS_Burden_SelfReport_sliderNegPos,  
EoS_Burden_FollowUp_sliderNegPos ) summary(burden_scores)
```

check if EoS is 1 per participant

```
burden_scores %>% count(connectionId) %>% arrange(desc(n))  
  
#keep uniqueness burden_scores <- burden_scores %>% distinct(connectionId, .keep_all =  
TRUE) nrow(burden_scores) length(unique(burden_scores$connectionId))
```

study period

```
study_period <- data_labeled %>% filter(formType %in% c("Morning", "Evening",  
"StressButton")) %>% group_by(connectionId) %>% summarise( start_date = min(date, na.rm =  
TRUE), end_date = max(date, na.rm = TRUE), n_days = as.numeric(end_date - start_date) + 1 )
```

exclude participants with 0 entries

```
study_period <- study_period %>% filter(!is.infinite(start_date) & !is.infinite(end_date))  
summary(study_period$n_days)
```

```
#create daily rows daily_rows <- study_period %>% rowwise() %>% mutate( date_list =  
list(seq.Date(start_date, end_date, by = "day")) ) %>% unnest(cols = c(date_list)) %>%  
rename(date = date_list) %>% select(connectionId, date) head(daily_rows, 10)
```

```
colnames(data_labeled)
```

```
#fix data labeled previous study items delete vars_to_remove <- c(
```

Baseline / unused stress variants

```
"baseline_Stressed_sliderNeutralPos", "stress_gespannen_sliderNeutralPos",  
"day_valence_sliderNeutralPos", "day_stress_line_continuousLine",
```

Affect & cognition (unused)

```
"affect_positive_sliderNeutralPos", "affect_negative_sliderNeutralPos",  
"cognitive_sliderNeutralPos",
```

Coping (unused)

```
"coping_unpl_multipleChoice_string", "Evening_handle_unpleasant_sliderNeutralPos",
```

Sleep (unused)

```
"sleep_sliderNegPos",
```

Stressor content (unused)

```
"stressor_event_multipleChoice_string" ) data_labeled <- data_labeled %>% select(-  
any_of(vars_to_remove)) colnames(data_labeled)
```

```
#check for baseline questionnaire table(data_labeled$formType, useNA = "ifany")
```

```
#create dataset for analysis vars_final <- c( "connectionId", "alias", "timeStampStart",  
"timeStampStop", "timeStampSent", "timeStampScheduled", "day_stress_sliderNeutralPos",  
"stressed_sliderNeutralPos", "coping_multipleChoice_string",  
"Evening_Coping_multipleChoice_string", "Evening_HandleStress_sliderNegPos",  
"Morning_SleepQuality_sliderNegPos", "Evening_stressors_open",  
"Evening_stressors_multipleChoice_string", "stressor_b_multipleChoice_string",  
"EoS_OverallExperience_sliderNegPos", "EoS_Recommend_sliderNegPos",  
"EoS_ClearityOfInstructions_sliderNegPos", "EoS_mPath_sliderNegPos",  
"EoS_Burden_Morning_sliderNegPos", "EoS_Burden_SelfReport_sliderNegPos",  
"EoS_Burden_FollowUp_sliderNegPos", "EoS_Burden_Evening_sliderNegPos",  
"EoS_AnythingElse_open", "questionListName", "date", "participantID", "formType" )
```

```
data_analysis <- data_labeled %>% select(all_of(vars_final)) colnames(data_analysis)
```

```
#daily rows str(daily_rows) head(daily_rows, 10) #create label/1 for completed submission
```

Morning submissions

```
morning_data <- data_analysis %>% filter(formType == "Morning") %>% select(connectionId,  
date) %>% mutate(morning_completed = 1)
```

Evening submissions

```
evening_data <- data_analysis %>% filter(formType == "Evening") %>% select(connectionId, date) %>% mutate(evening_completed = 1)
```

StressButton submissions

```
selfreport_data <- data_analysis %>% filter(formType == "StressButton") %>% select(connectionId, date) %>% mutate(selfreport_completed = 1)
```

Follow-up submissions

```
followup_data <- data_analysis %>% filter(formType == "Followup") %>% select(connectionId, date) %>% mutate(followup_completed = 1)
```

Collapse multiple submissions per day to 1

```
selfreport_data <- selfreport_data %>% group_by(connectionId, date) %>% summarise(selfreport_completed = 1, .groups = "drop")
```

```
followup_data <- followup_data %>% group_by(connectionId, date) %>% summarise(followup_completed = 1, .groups = "drop")
```

```
morning_data <- morning_data %>% group_by(connectionId, date) %>% summarise(morning_completed = 1, .groups = "drop")
```

```
evening_data <- evening_data %>% group_by(connectionId, date) %>% summarise(evening_completed = 1, .groups = "drop")
```

merge into daily rows

```
daily_rows <- daily_rows %>% left_join(morning_data, by = c("connectionId", "date")) %>% left_join(evening_data, by = c("connectionId", "date")) %>% left_join(selfreport_data, by = c("connectionId", "date")) %>% left_join(followup_data, by = c("connectionId", "date")) %>%
```

Replace NA with 0 (no submission)

```
mutate( morning_completed = ifelse(is.na(morning_completed), 0, morning_completed), evening_completed = ifelse(is.na(evening_completed), 0, evening_completed), selfreport_completed = ifelse(is.na(selfreport_completed), 0, selfreport_completed), followup_completed = ifelse(is.na(followup_completed), 0, followup_completed) )
```

```
colnames(daily_rows)
```

participant compliance

```
participant_compliance <- daily_rows %>% group_by(connectionId) %>% summarise( n_days =  
n(), morning_rate = mean(morning_completed), evening_rate = mean(evening_completed),  
selfreport_rate = mean(selfreport_completed), followup_rate =  
mean(followup_completed), .groups = "drop" )
```

```
head(participant_compliance) summary(participant_compliance)
```

remove outliers / non participant data

```
study_start <- as.Date("2025-11-10") study_end <- as.Date("2025-12-14")
```

```
participant_compliance <- participant_compliance %>% filter(n_days <= 17) # keep only  
participants with 20 days or fewer
```

```
summary(participant_compliance$n_days) range(daily_rows$date)
```

```
daily_rows <- daily_rows %>% filter(connectionId %in% participant_compliance$connectionId)  
daily_rows <- daily_rows %>% filter( connectionId %in%  
participant_compliance$connectionId, date >= study_start & date <= study_end )
```

Remove participants with very short participation (<5 days)

```
participant_compliance_filtered <- participant_compliance %>% filter(n_days >= 5, n_days <=
```

```
17
```

```
)  
#filter daily_rows to match daily_rows_filtered <- daily_rows %>% filter(connectionId %in%  
participant_compliance_filtered$connectionId)
```

filter eos burden score

```
eos_burden <- data_labeled %>% filter(formType == "Other", questionListName == "End of  
Study") %>% select( connectionId, EoS_Burden_Morning_sliderNegPos,  
EoS_Burden_Evening_sliderNegPos, EoS_Burden_SelfReport_sliderNegPos,  
EoS_Burden_FollowUp_sliderNegPos ) %>% distinct(connectionId, .keep_all = TRUE) #  
ensure 1 row per participant
```

merge

```
participant_data_filtered <- participant_compliance_filtered %>% left_join(eos_burden, by =  
"connectionId")
```

check

```
nrow(participant_data_filtered) summary(participant_data_filtered)
```

correlation perceived burden eos and response rate

```
cor_data <- participant_data_filtered %>% select( morning_rate, evening_rate, selfreport_rate,  
followup_rate, EoS_Burden_Morning_sliderNegPos, EoS_Burden_Evening_sliderNegPos,  
EoS_Burden_SelfReport_sliderNegPos, EoS_Burden_FollowUp_sliderNegPos ) cor_matrix <-  
cor(cor_data, use = "pairwise.complete.obs") cor_matrix
```

day cutoff response rate

```
daily_rows_days <- daily_rows_filtered %>% group_by(connectionId) %>% arrange(date) %>%  
mutate(day_number = row_number()) %>% ungroup()
```

Average compliance per day across participants

```
daily_compliance <- daily_rows_days %>% group_by(day_number) %>%  
summarise( morning_rate = mean(morning_completed, na.rm = TRUE), evening_rate =  
mean(evening_completed, na.rm = TRUE), selfreport_rate = mean(selfreport_completed, na.rm  
= TRUE), followup_rate = mean(followup_completed, na.rm = TRUE), n_participants = n() )  
library(ggplot2) daily_compliance_long <- daily_compliance %>% pivot_longer(cols =  
morning_rate:followup_rate, names_to = "component", values_to = "completion_rate")
```

```
ggplot(daily_compliance_long, aes(x = day_number, y = completion_rate, color = component))  
+ geom_line(size = 1.2) + geom_point() + labs( title = "Compliance Drop-Off Over Study  
Days", x = "Study Day Number", y = "Average Completion Rate", color = "Component" ) +  
theme_minimal()
```

plot days with at least 1 response per participant

```
daily_rows_filtered <- daily_rows_filtered %>% group_by(connectionId) %>%  
mutate(study_day = as.integer(date - min(date)) + 1) %>% ungroup()
```

```
daily_rows_filtered <- daily_rows_filtered %>% mutate( overall_completed =
ifelse( morning_completed == 1 | evening_completed == 1 | selfreport_completed == 1 |
followup_completed == 1, 1, 0 ) )
```

```
overall_compliance_by_day <- daily_rows_filtered %>% group_by(study_day) %>%
summarise( overall_compliance = mean(overall_completed, na.rm = TRUE), n_participants =
n(), .groups = "drop" )
```

```
library(ggplot2)
```

```
ggplot(overall_compliance_by_day, aes(x = study_day, y = overall_compliance)) +
geom_line(linewidth = 1) + geom_point(size = 2) + scale_y_continuous(limits = c(0, 1)) +
labs( x = "Study day", y = "Proportion of participants with any response", title = "Overall
compliance across study days" ) + theme_minimal()
```

```
#burden avg scores burden_long <- participant_data_filtered %>% select( connectionId,
EoS_Burden_Morning_sliderNegPos, EoS_Burden_Evening_sliderNegPos,
EoS_Burden_SelfReport_sliderNegPos, EoS_Burden_FollowUp_sliderNegPos ) %>%
pivot_longer( cols = -connectionId, names_to = "component", values_to = "burden" )
```

```
burden_summary <- burden_long %>% group_by(component) %>% summarise( mean_burden
= mean(burden, na.rm = TRUE), sd_burden = sd(burden, na.rm = TRUE), n =
sum(!is.na(burden)), .groups = "drop" ) burden_summary
```

```
ggplot(burden_summary, aes(x = component, y = mean_burden)) + geom_col() +
geom_errorbar( aes(ymin = mean_burden - sd_burden, ymax = mean_burden + sd_burden),
width = 0.2 ) + labs( x = "Study component", y = "Mean perceived burden (0–100)", title =
"Average perceived burden of study components" ) + theme_minimal() + theme(axis.text.x =
element_text(angle = 45, hjust = 1))
```

validity checks

```
stress_long <- data_analysis %>% filter(formType == "StressButton") %>% select(connectionId,
date, day_stress_sliderNeutralPos)
```

```
stress_long <- stress_long %>% group_by(connectionId) %>% mutate(study_day =
as.integer(date - min(date)) + 1) %>% ungroup()
```

```
stress_long <- data_analysis %>% filter( formType == "StressButton", connectionId %in%
participant_compliance_filtered$connectionId, date >= study_start, date <= study_end ) %>%
select(connectionId, date, day_stress_sliderNeutralPos)
```

```
#check summary(stress_long$day_stress_sliderNeutralPos) range(stress_long$date)

stress_by_day <- stress_long %>% group_by(study_day) %>% summarise( mean_stress =
mean(day_stress_sliderNeutralPos, na.rm = TRUE), sd_stress = sd(day_stress_sliderNeutralPos,
na.rm = TRUE), n = sum(!is.na(day_stress_sliderNeutralPos)), .groups = "drop" )
print(stress_by_day)
```

#Results extraction!!!

RQ1: Perceived burden means and distributions per component

```
burden_descriptives <- participant_data_filtered %>%
select( EoS_Burden_Morning_sliderNegPos, EoS_Burden_Evening_sliderNegPos,
EoS_Burden_SelfReport_sliderNegPos, EoS_Burden_FollowUp_sliderNegPos )

summary(burden_descriptives)
```

Freidmann test

Reshape to long format for within-subject comparison

```
burden_long <- participant_data_filtered %>% select(connectionId,
EoS_Burden_Morning_sliderNegPos, EoS_Burden_Evening_sliderNegPos,
EoS_Burden_SelfReport_sliderNegPos, EoS_Burden_FollowUp_sliderNegPos) %>%
pivot_longer( cols = starts_with("EoS_Burden"), names_to = "component", values_to =
"burden" )
```

Friedman test

```
friedman.test(burden ~ component | connectionId, data = burden_long)

#wilcoxon pairwise.wilcox.test( x = burden_long$burden, g = burden_long$component, paired =
TRUE, p.adjust.method = "holm" )
```

RQ1a: Correlations between perceived burden and compliance

```
burden_compliance_vars <- participant_data_filtered %>% select( morning_rate, evening_rate,
selfreport_rate, followup_rate, EoS_Burden_Morning_sliderNegPos,
EoS_Burden_Evening_sliderNegPos, EoS_Burden_SelfReport_sliderNegPos,
EoS_Burden_FollowUp_sliderNegPos )
```

```
cor_matrix <- cor( burden_compliance_vars, use = "pairwise.complete.obs", method =  
"pearson" )  
  
round(cor_matrix, 3)
```

Normality tests for compliance rates

```
shapiro.test(participant_data_filtered$morning_rate)  
shapiro.test(participant_data_filtered$evening_rate)  
shapiro.test(participant_data_filtered$selfreport_rate)  
shapiro.test(participant_data_filtered$followup_rate)
```

Normality tests for burden scores

```
shapiro.test(participant_data_filtered$EoS_Burden_Morning_sliderNegPos)  
shapiro.test(participant_data_filtered$EoS_Burden_Evening_sliderNegPos)  
shapiro.test(participant_data_filtered$EoS_Burden_SelfReport_sliderNegPos)  
shapiro.test(participant_data_filtered$EoS_Burden_FollowUp_sliderNegPos)
```

Histograms for compliance rates

```
hist(participant_data_filtered$morning_rate, main = "Morning compliance")  
hist(participant_data_filtered$evening_rate, main = "Evening compliance")  
hist(participant_data_filtered$selfreport_rate, main = "Self-report compliance")  
hist(participant_data_filtered$followup_rate, main = "Follow-up compliance")
```

Histograms for burden scores

```
hist(participant_data_filtered$EoS_Burden_Morning_sliderNegPos, main = "Morning burden")  
hist(participant_data_filtered$EoS_Burden_Evening_sliderNegPos, main = "Evening burden")  
hist(participant_data_filtered$EoS_Burden_SelfReport_sliderNegPos, main = "Self-report  
burden") hist(participant_data_filtered$EoS_Burden_FollowUp_sliderNegPos, main = "Follow-  
up burden")
```

Linearity

Morning

```
plot( participant_data_filtered$EoS_Burden_Morning_sliderNegPos,  
participant_data_filtered$morning_rate, xlab = "Morning burden", ylab = "Morning  
compliance" )
```

Evening

```
plot( participant_data_filtered$EoS_Burden_Evening_sliderNegPos,  
participant_data_filtered$evening_rate, xlab = "Evening burden", ylab = "Evening compliance" )
```

Self-report

```
plot( participant_data_filtered$EoS_Burden_SelfReport_sliderNegPos,  
participant_data_filtered$selfreport_rate, xlab = "Self-report burden", ylab = "Self-report  
compliance" )
```

Follow-up

```
plot( participant_data_filtered$EoS_Burden_FollowUp_sliderNegPos,  
participant_data_filtered$followup_rate, xlab = "Follow-up burden", ylab = "Follow-up  
compliance" )
```

spearman corelation because pearson was violated

```
cor_matrix_spearman <- cor( burden_compliance_vars, use = "pairwise.complete.obs", method =  
"spearman" )
```

```
round(cor_matrix_spearman, 3)
```

Create a vector of burden variables

```
burden_vars <- c( "EoS_Burden_Morning_sliderNegPos",  
"EoS_Burden_Evening_sliderNegPos", "EoS_Burden_SelfReport_sliderNegPos",  
"EoS_Burden_FollowUp_sliderNegPos" )
```

Create a vector of compliance variables

```
compliance_vars <- c( "morning_rate", "evening_rate", "selfreport_rate", "followup_rate" )
```

Initialize an empty data frame to store results

```
spearman_results <- data.frame( Burden = character(), Compliance = character(), Rho =  
numeric(), p_value = numeric(), stringsAsFactors = FALSE )
```

Loop through all combinations

```
for (b in burden_vars) { for (c in compliance_vars) { test <-  
cor.test( participant_data_filtered[[b]], participant_data_filtered[[c]], method = "spearman",  
exact = FALSE ) spearman_results <- rbind( spearman_results, data.frame( Burden = b,  
Compliance = c, Rho = round(test$estimate, 3), p_value = round(test$p.value, 3) ) ) } }
```

View results

```
spearman_results
```

```
#RQ1b
```

Compute average compliance per participant per component for Week 1 and Week 2

```
weekly_compliance <- daily_rows_filtered %>% mutate(week = ifelse(as.numeric(date -  
min(date)) < 7, "Week1", "Week2")) %>% group_by(connectionId, week) %>%  
summarise( morning_rate = mean(morning_completed, na.rm = TRUE), evening_rate =  
mean(evening_completed, na.rm = TRUE), selfreport_rate = mean(selfreport_completed, na.rm  
= TRUE), followup_rate = mean(followup_completed, na.rm = TRUE), .groups = "drop" ) %>%  
pivot_wider( names_from = week, values_from = c(morning_rate, evening_rate, selfreport_rate,  
followup_rate) )
```

Merge with burden scores

```
weekly_compliance_burden <- weekly_compliance %>%  
left_join( participant_data_filtered %>% select(connectionId, starts_with("EoS_Burden")), by =  
"connectionId" )
```

Spearman correlations for Week 1

```
cor_week1 <- cor( weekly_compliance_burden %>% select(morning_rate_Week1,
evening_rate_Week1, selfreport_rate_Week1, followup_rate_Week1,
EoS_Burden_Morning_sliderNegPos, EoS_Burden_Evening_sliderNegPos,
EoS_Burden_SelfReport_sliderNegPos, EoS_Burden_FollowUp_sliderNegPos), use =
"pairwise.complete.obs", method = "spearman" )
```

Spearman correlations for Week 2

```
cor_week2 <- cor( weekly_compliance_burden %>% select(morning_rate_Week2,
evening_rate_Week2, selfreport_rate_Week2, followup_rate_Week2,
EoS_Burden_Morning_sliderNegPos, EoS_Burden_Evening_sliderNegPos,
EoS_Burden_SelfReport_sliderNegPos, EoS_Burden_FollowUp_sliderNegPos), use =
"pairwise.complete.obs", method = "spearman" )
```

```
round(cor_week1, 3) round(cor_week2, 3)
```

```
#p values morning cor.test( weekly_compliance_burden$morning_rate_Week1,
weekly_compliance_burden$EoS_Burden_Morning_sliderNegPos, method = "spearman", exact
= FALSE )
```

```
cor.test( weekly_compliance_burden$morning_rate_Week2,
weekly_compliance_burden$EoS_Burden_Morning_sliderNegPos, method = "spearman", exact
= FALSE )
```

```
#RQ2 fixing 16 days evening report names(daily_compliance_long) daily_compliance_long_14
<- daily_compliance_long %>% filter(day_number <= 14)
```

```
ggplot(daily_compliance_long_14, aes(x = day_number, y = completion_rate, color =
component)) + geom_line(linewidth = 1) + geom_point() + scale_x_continuous( breaks = 1:14,
limits = c(1, 14) ) + scale_y_continuous( limits = c(0, 1) ) + labs( x = "Study Day", y =
"Completion Rate", color = "EMA Component" ) + theme_minimal()
```

Summary table per day and component

```
names(daily_rows_filtered)
```

Keep only study days 1–14

```
daily_filtered <- daily_rows_filtered %>% filter(study_day <= 14)
```

Reshape to long format

```
daily_long <- daily_filtered %>% pivot_longer( cols = c(morning_completed,  
evening_completed, selfreport_completed, followup_completed), names_to = "component",  
values_to = "completed" )
```

Compute daily completion rates and number of participants contributing

```
daily_summary <- daily_long %>% group_by(study_day, component) %>%  
summarise( completion_rate = mean(completed, na.rm = TRUE), n_participants =  
sum(!is.na(completed)), .groups = "drop" ) %>% arrange(component, study_day)
```

View the table

```
daily_summary print(daily_summary, n = 56)
```

```
#RQ3: Person-centered effect of Evening Stress on Compliance library(dplyr) library(lubridate)  
library(lme4)
```

Evening stress pro Tag extrahieren

```
evening_stress <- data_labeled %>% filter(formType == "Evening") %>% select(connectionId,  
date, Evening_Day_sliderNegPos) %>% rename(day_stress =  
Evening_Day_sliderNegPos) %>% distinct(connectionId, date, .keep_all = TRUE) # 1 Wert pro  
Teilnehmer/Tag
```

Daily compliance vorbereiten

SelfReport & FollowUp behalten die Anzahl der Einträge

```
daily_compliance <- daily_rows_filtered %>% select(connectionId, date, morning_completed,  
evening_completed, selfreport_completed, followup_completed)
```

Merge Evening stress mit Compliance

```
stress_compliance <- daily_compliance %>% left_join(evening_stress, by = c("connectionId",  
"date"))
```

Person centered Evening-Stress

```
stress_compliance <- stress_compliance %>% group_by(connectionId) %>% mutate(stress_pc =  
day_stress - mean(day_stress, na.rm = TRUE)) %>% ungroup()
```

Next-day lag

```
stress_nextday <- stress_compliance %>% group_by(connectionId) %>% arrange(date) %>%  
mutate( morning_nextday = lead(morning_completed), evening_nextday =  
lead(evening_completed), selfreport_nextday = lead(selfreport_completed), followup_nextday =  
lead(followup_completed) ) %>% ungroup() %>% filter(!is.na(morning_nextday)) # last day  
filtered out. no next day
```

Mixed-Effects-Model same day

```
model_morning_same <- lmer(morning_completed ~ stress_pc + (1 | connectionId), data =  
stress_compliance) model_evening_same <- lmer(evening_completed ~ stress_pc + (1 |  
connectionId), data = stress_compliance) model_selfreport_same <- lmer(selfreport_completed ~  
stress_pc + (1 | connectionId), data = stress_compliance) model_followup_same <-  
lmer(followup_completed ~ stress_pc + (1 | connectionId), data = stress_compliance)
```

Mixed-Effects-Model next day

```
model_morning_nextday <- lmer(morning_nextday ~ stress_pc + (1 | connectionId), data =  
stress_nextday) model_evening_nextday <- lmer(evening_nextday ~ stress_pc + (1 |  
connectionId), data = stress_nextday) model_selfreport_nextday <- lmer(selfreport_nextday ~  
stress_pc + (1 | connectionId), data = stress_nextday) model_followup_nextday <-  
lmer(followup_nextday ~ stress_pc + (1 | connectionId), data = stress_nextday)
```

summary models

```
summary(model_morning_same) summary(model_evening_same)  
summary(model_selfreport_same) summary(model_followup_same)
```

```
summary(model_morning_nextday) summary(model_evening_nextday)  
summary(model_selfreport_nextday) summary(model_followup_nextday)
```

