Investigating the Impact of Distress on the Effectiveness and Adherence to Ecological Momentary Interventions: A Micro-Randomised Trial

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Abstract

Background: Ecological Momentary Interventions (EMIs), particularly Just-in-Time Adaptive Interventions (JITAIs), provide timely mental health support, yet the optimal timing for delivery remains unclear. While JITAIs theoretically suggest high-distress moments as optimal for intervention, opposing literature exists. **Objective:** This study aimed to explore the impact of distress at intervention moments on the effectiveness and adherence to EMIs. **Method:** A smartphone-based Micro-Randomized Trial (MRT) was conducted with 72 participants experiencing mild distress. The trial spanned 23 days, where during the first week participants completed brief Ecological Momentary Assessments (EMAs) evaluating their momentary distress levels and adherence. Starting from the second week, in addition to EMAs, participants engaged in a series of four different EMIs till the end of the study. Mixed-effects models were used to analyse the data. **Results:** EMIs significantly reduced momentary distress during high-distress moments compared to low-distress moments ($\beta = -0.27$, $p = .002$). Adherence did not significantly differ between high and low-distress moments. However, being in an average-distress moment significantly decreased the likelihood of completing an EMI compared to a low-distress moment ($\beta = 0.65$, $p < .0001$). The likelihood of adherence during high-distress moments was significantly higher compared to average-distress moments ($\beta = 0.65$, $SE = 0.09$, $z = 7.64$, $p < .0001$). **Conclusion:** EMIs significantly reduced distress when delivered during high-distress moments, underscoring the critical timing of interventions. Adherence rates did not vary much between high and low-distress moments but were notably lower during average-distress moments. This study reinforces the need for well-timed interventions and future research.

Keywords: Ecological Momentary Interventions, Just-in-Time Adaptive Interventions, distress, Ecological Momentary Assessments, distress, Micro-Randomised Trial

According to the World Health Organisation, in 2019, approximately one billion people worldwide were reported to be suffering from mental disorders, with a considerable percentage lacking access to essential care (WHO., 2022). This observed disparity in mental health treatment accessibility is commonly referred to as the mental health treatment gap (Pathare et al., 2018). Various obstacles hinder individuals from accessing mental health services, encompassing attitudinal barriers such as a tendency for autonomous problem-solving and diminished recognition of the necessity for treatment (Andrade et al., 2014; Mojtabai et al., 2011). These challenges extend to broader social and economic factors, including mental health stigma and the associated costs for treatment (Corrigan et al., 2014; Kaur & Pathak., 2017). Looking for a solution, the European Commission (2023) argued that to address the pressing demand for preventive, easily accessible, and scalable mental health care, creative approaches and concerted action are urgently needed.

According to Kazdin & Blase (2011) and Naslund et al. (2017), technological advancements and increased use of smartphones enable innovative ways of providing psychological support. One such method is Ecological Momentary Interventions (EMIs), which offer accessible and affordable interventions to enhance mental health and foster well-being (Versluis et al., 2016). Heron & Smyth (2010) describe EMIs as brief, mobile-based psychological interventions targeting individuals during everyday activities. Research indicates that EMIs can improve depressive and anxiety symptoms, as well as perceived stress, with small to medium effect sizes (Gee et al., 2016; Linardon et al., 2019; Schueller et al., 2017).

Within the realm of EMIs, a specific class known as "just-in-time adaptive intervention" (JITAI) has gained prominence (Schueller et al., 2017). JITAIs take the concept of EMIs a step further by incorporating adaptive mechanisms that can tailor the timing, content, and delivery of interventions based on real-time data about the user’s internal and contextual changes (Schueller et al., 2017; Nahum-Shani et al., 2018). Importantly, for a JITAI to be effective, the individual must be (1) *receptive* to provided support and (2) be in a state of *opportunity* and/or *vulnerability* (Nahum-Shani et al., 2015).

According to Nahum-Shani et al. (2015), a *state of receptivity* is " …the person's transient tendency to receive, process, and use the support provided." Künzler et al. (2019) suggest that receptivity can be influenced by a variety of factors, including age, personality, and device type. Additionally, contextual factors such as location, day/time, phone battery level, phone interaction, and physical activity also play a significant role in determining a person's receptivity. For instance, if a JITAI in the form of a text message is triggered while a person is driving a car, their state of receptivity may be compromised as a person cannot complete the intervention (Nahum-Shani et al., 2015). Therefore, as adherence is definitive for the effectiveness of mobile-based interventions, being in a state of receptivity is essential (Borghouts et al., 2021; Nahum-Shani et al., 2015).

On the other hand, a *state of opportunity* occurs when one is susceptible to positive behavioural changes (Nahum-Shani et al., 2018). The key idea is that to help improve certain behavioural or cognitive patterns, it is important to spot moments when someone is ready to learn and give them the right support at those times (Nahum-Shani et al., 2015). A good example of leveraging such a state is the SitCoach JITAI for office workers, developed by van Dantzig et al. (2013). SitCoach sends messages encouraging physical activity via a smartphone after 30 minutes of uninterrupted computer use. This approach leverages the state of opportunity created by extended periods of inactivity, promoting positive behaviour change at a time when the individual is most likely to benefit from the intervention (Nahum-Shani et al., 2018). It helps steer a person's actions or thoughts in a positive direction gradually.

Finally, according to Nahum-Shani et al. (2014), a *state of vulnerability* is a moment when a person is at higher risk for adverse health outcomes due to a combination of stable factors (e.g., personality) and temporary factors (e.g., negative emotions). For example, consider an individual with a personality trait of high neuroticism who has just experienced a stressful day at work. The combination of their personality trait and the temporary stress creates a state of vulnerability, making them more likely to engage in unhealthy behaviour such as emotional eating or staying up late, which, when repeated, may develop into severe mental health issues (Dakanalis et al., 2023; Hertenstein et al., 2019). In such a vulnerable moment, JITAI should be triggered to help a person manage their high stress (e.g. in the form of an emotion-regulation exercise) (Nahum-Shani et al., 2015).

As states of receptivity, opportunity and vulnerability arise spontaneously during one's daily activities, it is generally impossible to employ in-person approaches to identify when support is needed and provide the appropriate type of assistance efficiently (Nahum-Shani et al., 2018). One way to investigate dynamic daily experiences and tailor the timing for providing interventions is an integration of Ecological Momentary Assessments (EMAs) (Stone et al., 2007). EMAs, characterised by brief momentary self-reports, capture one’s everyday life as it unfolds and permit the study of the stream of thought and/or behaviour at the moment when they occur (Hektner et al., 2007; Hormuth, 1986; Shiffman et al., 2008). Furthermore, EMAs can provide insight into the momentary changes and variations in the well-being of individuals that cannot be recorded by retrospective self-report measures (Vries et al., 2020). Thus, by integrating EMAs, JITAIs can assess states of vulnerability, opportunity and receptivity in real time and address them just at the right time (Schueller et al., 2017).

All in all, according to the theories behind JITAIs, certain states are considered more optimal for providing EMIs (Nahum-Shani et al., 2018; Schueller et al., 2017). However, the specifics of that optimal timing remain unclear. (Balaskas et al., 2021; Klasnja et al. 2015; Künzler et al., 2019). Specifically, there is a lack of research investigating the effects of psychological states, such as high stress and negative emotions, on effectiveness and adherence to EMIs.

On one hand, a state of vulnerability is considered an appropriate time to trigger an EMI because it is likely to lead to negative outcomes if left unaddressed (Nahum-Shani et al., 2015). Perski et al. (2021), reported that studies commonly used "if-then rules" to trigger interventions based on participants self-reporting negative affect such as negative emotions and high stress or contextual variables affecting their mood. For instance, Hoeppner et al. (2019) utilised EMAs to measure participants' moods and smoking cravings to determine if an intervention should be triggered. Similarly, O'Donnell et al. (2019) provided interventions when participants reported drinking alcohol or experiencing strong urges for alcohol consumption. Negative affects and contextual variables from these two studies are vulnerability moments, which are considered optimal moments to provide interventions (Kumar et al., 2013; Nahum-Shani et al., 2018).

On the other hand, there are differing views on the effects of being in a vulnerable state. For example, Zadra & Clore (2011) argued that negative emotions can reduce motivation to face challenges. Additionally, as noted by McKay et al. (2014) and Ye et al. (2018), stress can negatively impact perceived self-efficacy. Consequently, momentary negative emotions and high stress, which further in this paper will be referred to as *distress*, could diminish willingness to engage with and receptivity to EMIs, thereby reducing overall effectiveness and adherence.

In conclusion, while moments of distress are critical for intervention, as they are likely to lead to negative outcomes if left unaddressed, these same moments can also reduce the individual's motivation and perceived self-efficacy, potentially diminishing the effectiveness of the intervention. Therefore, it is essential to explore the effects of distress. Furthermore, understanding the effect of distress is essential for addressing ethical considerations related to user well-being. If intervening when a user is experiencing distress is indeed effective, it will empirically support a common practice of JITAIs. Conversely, if it is otherwise, it could prompt a re-evaluation of current intervention strategies, fostering a more evidence-based and user-centred approach in the development of JITAIs.

To investigate the effects of distress, a novel research design can be employed: the Micro-Randomized Trial (MRT). This experimental design involves repeatedly and randomly assigning participants to different intervention components (Golbus et al., 2021). As Klasnja et al. (2015) highlight, the MRT allows researchers to study proximal effects, track changes over time, and identify causal relationships, making it a powerful tool for understanding the nuanced impacts of different psychological states, and in the case of this study, of experiencing distress.

The Current Study

The objective of the current study was to explore the influence of experiencing distress on adherence to and effectiveness of EMIs. For that, mobile-based MRT was carried out in which participants had to answer EMAs and participate in EMIs. The EMIs included two Positive Psychology Interventions (PPIs), one exercise from Acceptance and Commitment Therapy (ACT), and one exercise from Cognitive Behavioral Therapy (CBT). These interventions aimed to reduce momentary distress.

It was hypothesised that 1) EMIs are more effective in reducing momentary distress when provided during high-distress moments compared to average or low-distress moments and 2) Participants are less likely to adhere to EMIs during high-distress moments compared to average or low-distress moments.

Methods

This study has been approved by the Ethics Committee of the Faculty of Behavioural, Management and Social Sciences (BMS) at the University of Twente under request #240007. Moreover, the study was pre-registered on the Open Science Framework (OSF) website (https://osf.io/z645p/).

Participants

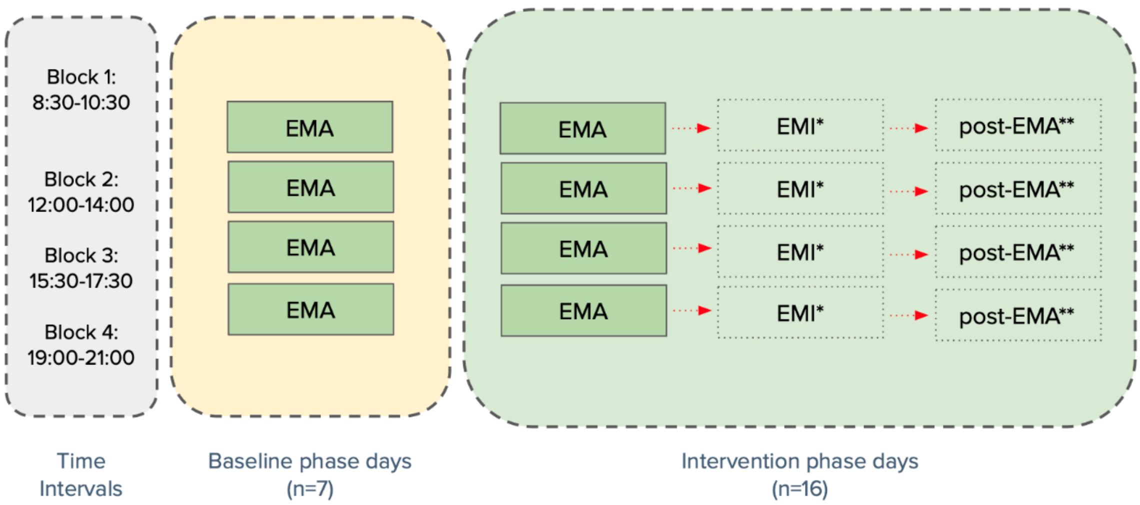
Initially, 376 individuals were invited to participate in the study, with the final sample of 72 participants. Based on power calculations for MRTs, using MRT-SS Calculator (https://pengliao.shinyapps.io/mrt-calculator/), 72 participants provide 80% power to detect a constant effect size of 0.1 (70% availability, 50% randomisation probability, 16 study days, 4 decision points per day, alpha = .05). Inclusion criteria were a good command of English, a minimum age of 18, and a Kessler Psychological Distress Scale (K-10) score of at least 20, indicating at least a mild level of distress (Yiengprugsawan et al., 2014). This cut-off was chosen because individuals experiencing psychological distress are at risk of developing mental health disorders (APA., 2018). Participants were recruited using convenience sampling through flyers with advertisements as well as such messaging and social media platforms as Instagram, Facebook, WhatsApp, and Telegram. Additionally, students from the University of Twente could access the study via SONA, the university's research portal. To encourage participation, individuals were offered a choice of rewards based on their compliance: 5 SONA credits (relevant for the University of Twente students) or a 50-euro Amazon voucher. For further details on the reward system, refer to the pre-registration.

Design

The study was conducted over 23 days and divided into two main phases: a *baseline phase* and an *intervention phase* (MRT design). During the baseline phase, participants completed four EMAs daily. Each EMA was triggered at random times within predefined intervals: 8:30-10:30, 12:00-14:00, 15:30-17:30, and 19:00-21:00. The semi-random sampling approach was chosen as it enhances ecological validity, reduces participant burden, and improves compliance by balancing fixed and random interval schemes, ensuring the intervals are roughly equal over time (Myin-Germeys & Kuppens, 2022). During the intervention phase, participants received four pre-EMAs daily, each followed by a post-EMA 30 minutes later. The pre-EMAs were randomly assigned within the same intervals used for EMAs in the baseline phase. After each pre-EMA, participants had a 50% chance of receiving an EMI during each interval. Participants were limited to receiving two interventions per day. Consequently, from Day 8 until the end of the study, participants could complete eight questionnaires daily and perform two exercises. For a visual representation refer to Figure 1.

Figure 1

Visualisation of a Baseline Phase and Intervention Phase Day



Note. * daily only two EMIs are triggered right after filling in an EMA. The intervals during which an EMI is provided are randomly assigned.
** a post-EMA is sent 30 minutes after a pre-EMA

The expiration time for both EMAs and EMIs was 30 minutes. In total, there were four different EMIs, and each was assigned to participants for four consecutive days to ensure sufficient learning of each EMI. To manage potential order effects, starting from the intervention phase, participants were randomly allocated to two groups that followed the EMIs in reverse order. Throughout the whole study, participants could receive up to 156 EMAs and 32 EMIs.

Measures

The EMAs were constructed utilising the ESM Item Repository (https://esmitemrepositoryinfo.com/). EMAs during the baseline phase and pre-EMAs during the intervention phase consisted of 13 items each. The post-EMAs during the intervention phase included 10-12 items, with two items dependent on whether an EMI was scheduled. Detailed description of each item can be found in pre-registration. For this study's main and sensitivity analyses, negative affect and adherence items were used.

Negative Affect Items

The distress was measured in every EMA throughout the whole study period with two negative affect items, using scales from 1 (Not at all) to 7 (Very much). Specifically, participants rated the statements "*Right before the notification, I felt stressed*" and "*Right before the notification, I felt down.*" Studies by Myin-Germeys et al. (2000) and Matcham et al. (2019) distress was measured in a similar way.

Adherence

Adherence was measured at the start of post-EMAs in blocks with a scheduled EMI beforehand. Participants answered the question, *"Did you do the exercise?"* by selecting either *YES* or *NO*.

Interventions

For the study purposes, two PPIs, one ACT exercise, and one CBT were implemented. The first PPI was a gratitude journal exercise, where participants listed three things they were grateful for and reflected on why these things inspired gratitude. The second

PPI involved savouring a positive memory, where participants recalled a happy memory in detail, focusing on the emotions experienced during the event. The ACT exercise aimed to help participants accept and embrace negative emotions rather than resist them. Participants were guided to stay present with their difficult feelings, observing them without trying to control or eliminate them. The CBT exercise focused on reframing negative thoughts to perceive situations more positively. Participants were encouraged to challenge their unpleasant thoughts, consider more realistic and positive interpretations, and recognize that negative thoughts are often not the most realistic explanations. For further details on used EMIs, see pre-registration.

Procedure

The study began with the recruitment phase, where potential participants were directed to the study website via advertisements with QR codes, social media posts or through the SONA system. They could register by completing a Qualtrics questionnaire, where they had to provide their email address and phone number. Researchers then added these details to an Excel file and assigned a personal ID to each participant. Participants received an email containing their personal ID and a link to a Qualtrics screening questionnaire, which assessed their age and K-10 score. If participants were eligible, they were invited via email to a twenty-minute briefing session with one of the researchers. If they were not eligible, they received an email informing them that they could not participate.

During the briefing session, the study's purpose and procedure were explained. Participants were introduced to the EMIs and helped with downloading and navigating the m-Path app. The sessions emphasised the importance of completing EMAs within thirty minutes of notification and spending at least ten minutes on each exercise. Participants chose between SONA credits or financial rewards, with the reward system explained if applicable. Finally, they received links to pre-questionnaires, which had to be completed before the study began the following Monday. After the 23rd day of the study, participants received the last email with the link to the post-questionnaire, in which they could choose their preferred reward and answer demographic as well as rate their experience with EMIs and study in general. For more details, refer to the pre-registration.

Data Analysis

To address test both hypotheses, mixed-effects models were used to account for the repeated measures design and the hierarchical structure of the data. Estimated marginal means (EMMs) and pairwise comparisons were also calculated. P-values with a significance level of $\alpha=0.05$ were used for all statistical tests. All analyses were conducted using R version 2024.04.1+748 with the lme4, lmerTest and emmeans packages.

To prepare for the main analyses, the momentary distress during the intervention phase was categorised into high, average, and low-distress moments for each participant. This categorisation enabled the investigation of the moderation effect of different distress moments. First, person-specific means and person-specific standard deviations (SD) were calculated based on the reported momentary distress values during the baseline phase of the study. These baseline values were then used to categorise pre-EMA distress during the intervention phase. Specifically, pre-EMA distress scores greater than +0.5 SD above the baseline mean were classified as high-distress moments, scores within ±0.5 SD of the baseline mean were classified as average-distress moments, and scores less than -0.5 SD below the baseline mean were classified as low-distress moments.

Due to the imbalance in the number of observations across different distress moments, weighted mixed-effects models were used to ensure that the results were not biased by the overrepresentation of any distress level (Bailey et al., 2019). The weighting process involved calculating the size of each distress moment group and assigning weights inversely proportional to these sizes. This method ensures that observations from smaller groups are given higher importance, thereby balancing the dataset (Mansournia & Altman., 2016). Additionally, the weights were normalised so that their mean equals 1, to easier facilitate interpretation and ensure proportionality in later analyses.

To test the first hypothesis linear mixed effect model fitted with REML estimator was used. The dependent variable was momentary distress assessed at post-EMA. Fixed effects included distress moment (high-distress moment, average-distress moment, low-distress moment), which was treated as a factor variable. The other fixed effects were the completion of an EMI (yes/no) and its interaction with the distressed moments. Observations nested within participants were included as random intercepts.

To test the second hypothesis, the logistic mixed-effects model was used. The dependent variable was adherence measured as completion of an EMI (yes/no). Fixed effects included distress moment (high-distressed, average-distress, low-distress), which was treated as a factor variable. Observations nested within participants were again included as random intercepts.

Results

Sample Description

The age of participants ranged from 18 to 34 (M_{age} = 20.90; SD_{age} = 3,66), with 67.6 % of them being female. Most of them were students (41) or working students (18), had German (24) or Dutch (19) nationalities, and had at least a high-school diploma (35) or bachelor's degree (22). Socio-demographic data from the participants can be seen in Table 1. The average response rate to EMAs was 71.80% (18.59% - 99.36%), and the average adherence to EMIs was 61.20% (6.25% - 100%). The study had a 0% dropout rate, while questionnaires before and after the main study period were completed by 98.6% of participants.

Table 1

Socio-Demographic Data of the Sample

	n (%)	*M (SD)*
Age		22.90 (3.66)
Gender		
Female	48 (67.61%)	
Male	21 (29.58%)	
Non-binary / third gender	1 (1.41%)	
Prefer not to say	1 (1.41%)	
Nationality		
Germany	24 (33.80%)	
Netherlands	19 (26.76%)	
Spain	3 (4.23%)	
India	2 (2.82%)	
Latvia	2 (2.82%)	
Sri Lanka	2 (2.82%)	
Ukraine	2 (2.82%)	
Other	18 (25.35%)	
Education		
Bachelor's degree	22 (30.99%)	
Doctoral degree	1 (1.41%)	
High school	35 (49.30%)	
Master's degree	9 (12.68%)	
Some college but no degree	4 (5.63%)	
Occupation		
Employed full time	2 (2.78%)	
Employed part time	8 (11.11%)	
Student	41 (56.94%)	
Unemployed looking for work	3 (4.17%)	
Working student	18 (25.00%)	

Note. N = 2,796 observations from 72 participants.

Descriptive Statistics

Table 2 provides an overview of the distribution of distress moments and the frequency of scheduled and completed EMIs during the study period. The data show that average-distress moments were the most frequent, followed by low-distress and high-distress moments. Each participant had an average of 32 scheduled EMIs, with the number of completed EMIs ranging from 1 to 30. The average completion rate of EMIs per participant was 16.67.

Table 2

Descriptive Statistics of Distress Moments and EMIs

	N	Min	Max	M
Low-distress levels	1996			
Average-distress levels	3067			
High-distress levels	1561			
Scheduled EMIs	2304	32	32	32
Completed EMIs	1200	1	30	16.67

Impact of Distress Moments on the Momentary Distress

Table 3 presents the results of the linear mixed-effects model assessing the effect of completion EMI during different distress moments on momentary distress. The low-distress moments were used as the reference category. First, completion of EMI during high-distress moments resulted in a significant reduction in momentary distress compared to low-distress moments, $\beta = -0.27$, SE = 0.09, $t(2750) = -3.14$, $p = .002$. Second, completion of EMI during average-distress moments did not result in a significant reduction in momentary distress compared to low-distress moments, $\beta = -0.16$, SE = 0.10, $t(2744) = -1.57$, $p = .12$.

Table 3

Summary of Linear Mixed Model Analysis on Momentary Distress

Predictor	Estimate	SE	df	t	p
(Intercept)	1.07	0.07	363.1	14.86	< .001
Pre-EMA Distress	0.66	0.03	879.9	23.90	< .001
High-Distress Moment	-0.14	0.10	1254	-1.37	.17
Average-Distress Moment	0.04	0.08	2441	0.55	.58
EMI: Completed	-0.001	0.06	2760	-0.02	.99
EMI*High-Distress	-0.27	0.09	2750	-3.14	.002
EMI*Average-Distress	-0.16	0.10	2744	-1.57	.12

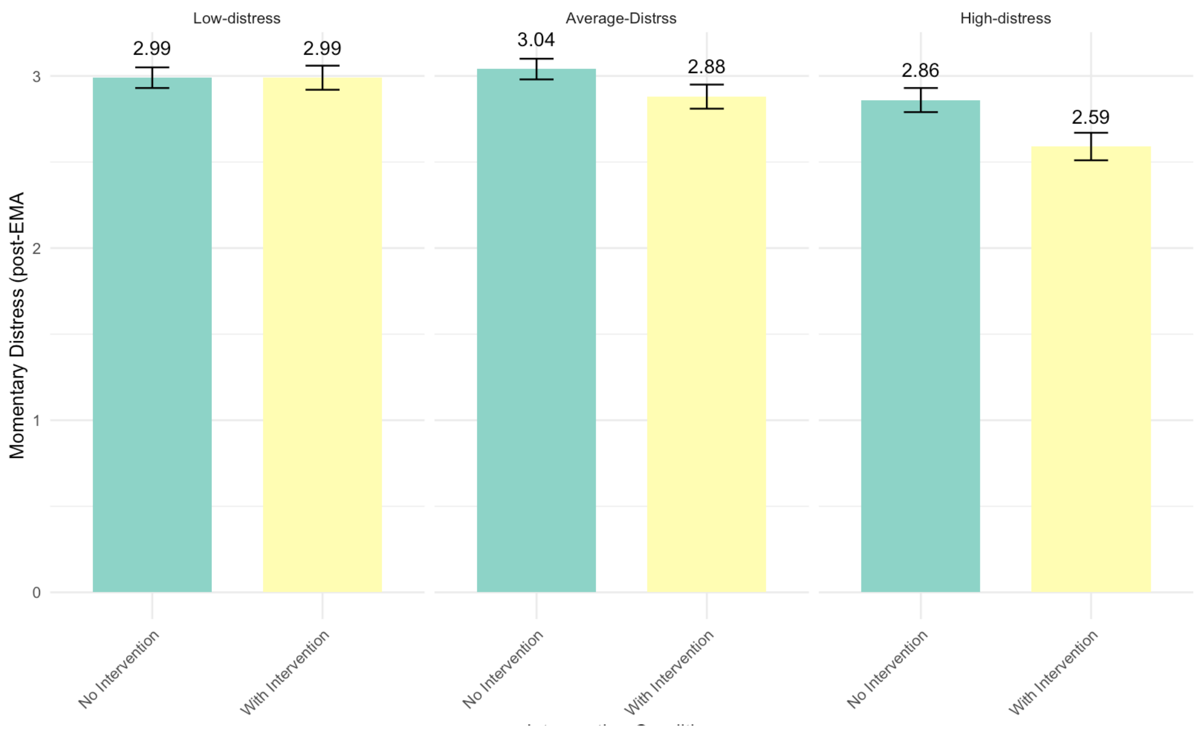
Note. predictor variables are weighted and normalised so the estimates cannot be interpreted as observed differences.

To get a clearer picture of the effect of different distress moments and completion of EMI on momentary distress, the EMMs were calculated and visualised in Figure 2. Additionally, pairwise comparisons were conducted to compare the effect of completing an

EMI during high-distress moments with average-distress moments. Completion of EMI during high-distress moments resulted in significantly lower momentary distress compared to the average-distress moment (β = -0.29, SE = 0.09, t(2267) = -3.19, p = .02).

Figure 2

Estimated Marginal Means of Momentary Distress by Distress Moments and Completion of EMI



Impact of Distress Moments on Completion of EMIs

Table 5 presents the results of the logistic mixed-effects model assessing the completion of EMIs by distressed moments. The results indicated that the baseline log-odds of completing an EMI during low-distress moment were significantly negative (β = -1.33, p < .001). The effect of being in a high-distress moment on completing an EMI was not statistically significant compared to a low-distress moment (β = 0.02, p = .824). However, being in an average-distress moment significantly decreased the likelihood of completing an EMI compared to being in a low-distress moment (β = -0.64, p < .001).

Table 5

Fixed Effects from Logistic Mixed-Effect Model for EMI Completion

Predictor	Estimate	SE	z-value	p-value
(Intercept)	-1.33	0.08	-17.08	< .001
High-Distress Moment	0.02	0.08	0.22	.824
Average-Distress Moment	-0.64	0.09	-7.41	< .001

Note. predictor variables are weighted and normalised so estimates cannot be interpreted as observed differences.

To further investigate the effects of different distress moments on the completion of EMI, EMMs were calculated. Pairwise comparisons between high-distress and average-distress moments were then conducted to determine the significance of the differences. Results showed that the likelihood of adherence was significantly higher in the high-distress moments compared to the average-distress moments ($\beta = 0.65$, SE = 0.09, $z = 7.64$, $p < .0001$).

Discussion

The purpose of this study was to explore the effect of momentary distress on the effectiveness and adherence to EMIs. Firstly, completing EMI during high-distress moments significantly reduced momentary distress compared to average and low-distress moments. Therefore, the first hypothesis “EMIs are more effective in reducing distress when provided during high-distress moments compared to average or low-distress moments” was accepted. Secondly, the adherence to EMIs during high-distress moments did not significantly differ from low-distress moments, however, the likelihood of adherence was significantly higher than during average distressed moments. Additionally, the likelihood of completing EMI during average-distress moments was lower compared to low-distress moments. Thus, the second hypothesis “Participants are less likely to adhere to EMIs during high-distress moments compared to average or low-distress moments” was rejected.

Momentary Distress and EMI Effectiveness

This study empirically confirms that EMIs are more effective in decreasing momentary distress during high-distress moments compared to low-distress moments. This finding supports the theoretical framework of JITAIs, which suggests that timely interventions during vulnerable moments can maximise their effectiveness (Nahum-Shani et al., 2018). Therefore, when constructing a JITAI study, high-distress moments should be utilised as triggers for providing EMIs.

Important to mention, that in this study, moments of vulnerability were characterised as high-distress moments, however, the conceptualisation of vulnerability and opportunity moments remains somewhat ambiguous in the context of mental health JITAIs (Balaskas et al., 2021). Future research could further empirically validate and refine our understanding of these moments to enhance intervention effectiveness. For example, integrating multi-modal data, such as physiological measures (e.g., heart rate, cortisol levels) alongside self-reported distress levels, can help distinguish between different types of vulnerability and opportunity moments (e.g. acute vs. chronic distress) as well as provide a more comprehensive conceptualisation of both vulnerability and opportunity moments (Sheikh et al., 2021; Yang et al., 2023).

Momentary Distress and EMI Adherence

The study's findings on adherence are somewhat complex. There was no significant difference in adherence to EMIs during high-distress moments compared to low-distress moments. However, participants were more likely to adhere to EMIs during both high and low-distress moments compared to average-distress moments. One possible explanation for this is that participants perceived EMIs as particularly relevant and useful during high-distress moments because they felt a greater need for support. On one hand, this explanation aligns better with the concept of moments of opportunity rather than moments of vulnerability (Nahum-Shani et al., 2018). However, it can be argued that due to the lack of concrete conceptualisation, high-distress moments can be considered both moments of opportunity and moments of vulnerability. Whereas, in low-distress moments, it is possible that participants were simply more receptive towards EMI (Nahum-Shani et al., 2015). All in all, these results underscore the importance of tailoring interventions to engage users during times of high and low distress, given that adherence to interventions is critical for their effectiveness (Kelders et al., 2012; Perski et al., 2017).

Furthermore, Klasnja et al. (2015) emphasized the need to consider various contextual factors (e.g. user's current activity, location, etc.) to enhance adherence. Future studies should investigate how additional contextual factors, such as time of day or specific environmental cues, influence adherence to EMIs. For example, it could be the case that during certain periods throughout the day, people are less likely to engage and be responsive to EMIs (Brandslet et al., 2021). Research indicates that during certain periods, such as the post-lunch dip, individuals may experience declines in cognition and concentration (Dhillon et al., 2017). Additionally, our body's circadian rhythm, which regulates mood, typically results in higher body temperature and alertness levels in the late morning to early afternoon, contributing to better moods during these times (Weir, 2018). Additionally, factors like user engagement, intervention design, and the personalization of content can impact adherence rates (Yardley et al., 2016). It seems that interventions that are perceived as more relevant and personalized tend to have higher adherence rates (Michie et al., 2017). Thus, future research should also explore how personalising EMIs to align with individual user preferences and contexts can improve adherence. It might be particularly interesting to implement algorithms that tailor EMIs based on contextual factors such as time of day, location, and user activity. For example, during the post-lunch dip, EMIs could include shorter, more engaging activities that are easier to complete with lower cognitive load.

Additionally, it could be exciting to allow users to personalise their EMI content by incorporating their own goals, or preferences.

Limitations and Strengths

There are at least five potential limitations concerning the results of this study. The first limitation is the relatively small sample size, which, although sufficient for the MRT design, may limit the generalisability of the findings.

Second, the power analysis targeted the main effects of EMIs on proximal outcomes. So, this study is underpowered to detect moderation effects accurately. This limitation raises the risk of Type 2 errors in the moderation analyses (Christley, 2010).

The third limitation is the reliance on self-report measures for assessing distress, which, despite providing real-time data, are subject to biases and inaccuracies inherent in self-reporting (Shiffman et al., 2008). Future studies may want to use more objective measures or various passive data collection techniques such as sensors or biosensors (Colombo et al., 2019).

The fourth limitation is that this study did not account for the effect of different EMIs. PPI, CBT, and ACT exercises could have different effects on the results of participants, but this study did not distinguish between the various EMIs. Instead, it treated them all as one category. Possibly, such an approach overlooked significant differences in the effectiveness of these EMIs. Thus, future studies should investigate the effects of each EMI separately to comprehend their unique contributions.

The fifth limitation is that this study did not directly address participants' receptivity to EMIs. According to Nahum-Shani et al. (2018), understanding and incorporating receptivity into JITAI designs can significantly enhance intervention adherence. Thus, future research should explore how to ensure that interventions are delivered not only at vulnerable moments but also when users are most likely to engage with them. For example, engaging participants in the design process of EMIs can ensure that the interventions are user-centred and relevant. By involving participants in focus groups, interviews, and usability testing, researchers can gain insights into what makes interventions appealing and acceptable to users, thereby enhancing their engagement and adherence.

Despite these limitations, the present study has several strengths. First, the use of MRTs to deliver EMIs allowed for drawing conclusions about momentary distress, which would not be possible with other methods (Klasnja et al., 2015). Second, the focus on an at-risk group with elevated levels of distress increases the clinical relevance of the findings, demonstrating the potential of EMIs to provide meaningful support to those in need.

Implications

The findings of this study have several important practical implications. For instance, mental health professionals and app developers should focus on delivering EMIs during high-distress moments to maximise their effectiveness. This targeted approach can provide immediate relief when individuals are most in need. Additionally, public health initiatives can also benefit from incorporating EMIs into their mental health strategies, especially during times of crisis or high public stress. Providing accessible, timely interventions can help mitigate widespread distress and promote community well-being. Finally, educational institutions can adopt EMIs to support students during stressful times, such as exam periods. By delivering interventions at peak distress moments, schools and universities can help improve students' mental health and academic performance.

Conclusion

The present study enhanced the understanding of the relationship between momentary distress and the effectiveness and adherence to EMIs. The findings suggest that interventions during high-distress moments can significantly enhance the effectiveness of digital mental health interventions. Moreover, high-distress moments do not lead to lower adherence.

Therefore, momentary distress can be used as a decision point to provide EMIs. This study contributes to a growing body of evidence supporting the strategic delivery of mental health support to improve well-being. By targeting high-distress moments, EMIs can provide critical and effective support.

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