The Role of Context Factors in Ecological Momentary Interventions for Mental Health Promotion: A Micro-Randomised Trial

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Abstract

Background Mental health problems are widespread, imposing a significant burden on both individuals and society. At the same time, Ecological Momentary Interventions (EMIs), facilitated through mobile devices, offer scalable and low-threshold treatment options for individuals within their daily lives. While previous studies have acknowledged the importance of context factors (e.g., social company, current location, activity) for EMIs, no studies to date have investigated their influence on EMI effectiveness and adherence in promoting mental health.

Methods In this smartphone-based micro-randomised trial, 72 distressed participants followed a transdiagnostic set of EMIs for 16 days and filled in brief Ecological Momentary Assessments (EMAs) evaluating their context, positive and negative affect, and adherence to EMIs. (Generalised) linear-mixed effects models were used to analyse the multilevel data.

Results On average, participants filled in 71.80% of EMAs and adhered to 61.20% of EMIs. Context did not significantly moderate the effects of EMIs on positive and negative affect. However, adherence to EMIs was significantly predicted by being in a home environment or following passive activities. EMI adherence did not significantly differ between being alone or with others but was high in both contexts and comparable to being in a home environment or following passive activities.

Conclusion Despite the non-significant results on EMI effectiveness, it cannot be concluded that tailoring EMIs to context is ineffective. Instead, a more nuanced assessment of context is needed. While home environments and passive activities are feasible contexts for EMI delivery, co-occurrence of receptivity, vulnerability and opportunity is vital to enhance EMI effectiveness. Further research on passive activities and engagement with EMIs is required.

Introduction

Worldwide, nearly 1 billion people are living with a mental health condition (WHO, 2022). However, the need for sufficient treatment options is often not met and accessing them can be challenging (WHO, 2022). At the same time, many people not diagnosed with a mental health condition report everyday psychological distress that impairs their well-being (Borghouts et al., 2021; Anderson et al., 2014). Psychological distress encompasses symptoms of stress, anxiety, and depression and is commonly, though not exclusively, linked to work-related factors such as work-life balance or job dissatisfaction (Viertiö et al., 2021; Anderson et al., 2014). People experiencing increased psychological distress are also at-risk of developing a mental health condition (Viertiö et al., 2021; APA, 2018). The development of smartphone-based Ecological Momentary Interventions (EMIs) could potentially support people living with a mental health condition or experiencing psychological distress since access to smartphones is growing globally (Naslund et al., 2017; Doherty et al., 2020; Borghouts et al., 2021). EMIs constitute "*momentary health treatments provided via hand-held mobile technologies that deliver psychological interventions while people are engaged in their typical routines in their everyday life*" (Schueller et al., 2017, p. 540).

While EMIs could increase worldwide access to mental healthcare, they also reform the treatment of mental health conditions by fostering the transition from traditional face-to-face therapy settings towards digital treatments people can use within daily life and personal context (Schueller et al., 2017). Therein, EMIs provide both scalable and low-threshold treatment options for mental health (Bell et al., 2023). At the same time, previous studies indicate that EMIs are effective in reducing depressive, anxiety and psychotic symptoms (Everitt et al., 2021; Schueller et al., 2017; Dao et al., 2021). In addition, many EMIs address positive affect (PA) and negative affect (NA) outcomes (Pavlacic et al., 2022; Rauschenberg et al., 2021, Everitt et al., 2021), which are highly dynamic and therefore enable the assessment of short-term,

momentary EMI effectiveness (Cloos et al., 2023). Moreover, PA and NA are important constructs connected to general well-being and distress (Póka et al., 2024; Huang et al., 2022).

EMI Effectiveness and States of Vulnerability/Opportunity

Naturally, integrating psychological treatment through EMIs into the day-to-day activities of people requires additional considerations. For example, to increase the effectiveness of EMIs, they should be provided during states of vulnerability and opportunity (Nahum-Shani et al., 2015). Negative (mental) health outcomes determine the vulnerability of a person and depend on a combination of more stable characteristics (e.g. personality) and dynamic contexts (e.g. current location, social company, activity). In contrast, opportune states occur when a person needs an EMI and can learn from it (Nahum-Shani et al., 2015). For instance, an individual with alcohol use disorder at a club with friends is in a vulnerable state due to the context. This situation also represents a state of opportunity, as the individual needs support and can gain insights into how location and social company might affect drinking behaviour (Nahum-Shani et al., 2015).

As the individual's context substantially fluctuates over the course of a day, EMIs must be adapted accordingly (De Vries et al., 2021; Dao et al., 2021; Kwasnicka et al., 2016; Conner & Norman, 2017) to exploit states of vulnerability and opportunity thereby ensuring EMI effectiveness. Dynamic adaptation of EMIs to the individual's context might therefore yield further benefits in terms of engagement, sustained behavioural change, and health outcomes (Dao et al., 2021; Kwasnicka et al., 2016; Conner & Norman, 2017; Müller-Riemenschneider et al., 2008). Although some studies have attempted to tailor the provision of EMIs to momentary context, it has not been directly tested whether this approach is more beneficial or which context factors are most relevant for EMI effectiveness (Burns et al., 2011; Klasnja et al., 2019). For example, Burns et al. (2011) attempted to provide depressed participants with EMIs based on their current location, resulting in significant mental health improvements.

However, they only analysed EMI effects, but not effects of context, on depression outcomes. Similarly, Klasnja et al. (2019) found that a context-tailored EMI significantly increased walking activity. However, they only compared the effect of delivering an EMI versus not delivering one, not the effectiveness of context-tailored versus non-tailored EMIs. Taken together, it remains unclear whether tailoring EMIs to context increases their effectiveness and which context factors are most relevant.

EMI Adherence and States of Receptivity

Another important factor is adherence since low adherence to EMIs undermines their effectiveness (Laure et al., 2023; Borghouts et al., 2021). In that regard, states of receptivity must be considered to enable people to adhere to EMIs in their daily life (Nahum-Shani et al., 2015; Bidargaddi et al., 2020). Receptivity refers to *"the conditions in which a person can receive, process, and use the support provided"* (Nahum-Shani et al., 2015, p.4). For example, a person who is driving is not receptive to a visual EMI provided through a smartphone notification (Nahum-Shani et al., 2015) since the individual is not able to receive (e.g. open the notification), process (e.g. understand the EMI) and use (e.g. follow the EMI instructions) the EMI safely. This example highlights the importance of momentary context once again.

Understanding how context affects receptivity to EMIs is crucial for facilitating EMI adherence (King et al., 2023). Previous research shows that users often abandon EMIs after a few interactions (Nahum-Shani et al., 2018) and that EMIs must align with users' needs to improve adherence (Laure et al., 2023; Van Gemert-Pijnen et al., 2011; Lattie et al., 2019). Only one study has investigated the influence of context on receptivity to a physical activity EMI (Künzler et al., 2019). The study found that context significantly correlated with participants' receptivity to the EMI, and the EMI was more effective when participants were receptive towards it. Additionally, EMI effectiveness enhanced participants' receptivity to subsequent EMIs (Künzler et al., 2019), highlighting the interconnectedness of context, EMI

adherence, and EMI effectiveness. However, it remains unclear whether these finding translate to EMIs focusing on mental health promotion.

The Present Study

The research objective of the present study focused on investigating the influence of context factors on EMI effectiveness and adherence. To address this objective, a micro-randomised trial (MRT) was conducted in which participants experiencing psychological distress received EMIs on their smartphones. The MRT is a novel research method that enables the assessment of EMI effects on momentary mental health outcomes, such as PA and NA, within natural contexts and on the individual level through random assignment of EMIs at specific decision points (Klasnja et al., 2015; Bhide et al., 2018; Bidargaddi et al., 2020). Since MRTs repeatedly randomise whether participants receive an EMI or not over the course of a study, they also enable researchers to draw causal conclusions (Klasnja et al., 2015). Furthermore, insights from MRTs can inform the development of optimised EMIs (Klasnja et al., 2015). For example, in which contexts distressed people are vulnerable and receptive and therefore should receive an EMI. In the present study, the following research questions (RQs) were addressed:

1. Does context (i.e. current location, social company, activity) moderate the effects of EMIs on PA and NA outcomes?
2. Is adherence to EMIs influenced by context (i.e. current location, social company, activity)?

Context, adherence, PA and NA were assessed with Ecological Momentary Assessments (EMAs; short questionnaires filled in by the participants multiple times per day on a mobile phone). Regarding RQ1, it was hypothesised that EMIs would be more effective in states of vulnerability and opportunity (Nahum-Shani et al., 2015), which are often work-related in people who experience psychological distress (Viertiö et al., 2021; Anderson et al., 2014).

Therefore, the relationship between EMIs and mental health outcomes was expected to be moderated by context, such that EMIs increase PA and decrease NA more if participants are at work/school (current location), working/studying (activity), or together with colleague(s) or peer(s) from uni/school (social company).

Regarding RQ2, it was hypothesised that adherence to EMIs is higher if participants were in states of receptivity and thus could easily receive, process, and use EMIs (Nahum-Shani et al., 2015). In specific, it was expected that participants have a higher adherence probability in home environments (current location; i.e. at home, at family/friend's place), when being alone (social company), or when following comparatively passive activities (activity; i.e. doing nothing, resting, passive free-time like TV, computer, video games, reading, and mobile phone/social media).

Methods

The study was pre-registered via the Open Science Framework (OSF) (https://osf.io/z645p/). Study approval was given by the ethics committee of the Faculty of Behavioural, Management and Social Sciences at the University of Twente (#240007).

Participants

Participants were recruited by the researchers through their personal networks, distributing flyers at the campus of the University of Twente and Saxion University of Applied Sciences (Enschede), and sharing the study on social media platforms and on SONA (recruitment platform of the University of Twente where students can sign-up for participating in studies). Participants were eligible if they were at least 18 years old, had sufficient command of the English language and experienced mild distress as determined by a score of >19 on the Kessler Psychological Distress Scale (K10) (Kessler et al., 2003). Participants were compensated with an Amazon voucher of up to 50€ or up to 5 SONA credits.

72 participants were included as determined by a power analysis for detecting a significant effect of EMIs on proximal mental health outcomes in a micro-randomised trial (Seewald et al., 2016). This sample size was sufficient to reach 80% power to detect a constant effect size of 0.1 (expected availability = 70%, randomisation probability = 50%, 16 study days and 4 decision points per day, alpha = .05).

Procedure

Data was collected between 12/03/2024 and 30/05/2024. Participants could register for the study by filling in an initial Qualtrics survey shared on a dedicated website for the study (https://www.utwente.nl/en/bms/mobile-health/). The survey asked for informed consent of the participants and their contact details. After registration, participants had to fill in the K10 to assess their degree of distress. Based on their K10 score, eligible participants received an invitation for a 20-minute briefing with a researcher. The briefing was done online via

Microsoft Teams or Zoom, followed a standard operating procedure (see pre-registration for details), and mainly focused on explaining the study procedure to participants and installing and testing the required m-Path app together. Participants also followed a demo questionnaire and received explanations about the items. It was emphasised that participants keep following their typical routines, do not adjust to the study, and open notifications as soon and as often as possible. At the end of the briefing, participants received a link to the Qualtrics pre-questionnaire that they needed to fill in before the upcoming Monday.

EMAs and EMIs were conducted with m-Path (Version 2.8.3), a platform that enables "real-time monitoring and real-life interventions" (https://m-path.io/landing/) via a smartphone app for research and blended care. Participants used the m-Path app on their private smartphones. The app notified participants about EMAs and EMIs. All participants received their first notifications on the Monday after their briefing to account for effects of weekdays (De Vries et al., 2021).

After the study period ended, participants received a link to the Qualtrics post-questionnaire, which was generally similar to the pre-questionnaire but included two additional sections regarding usability and engagement.

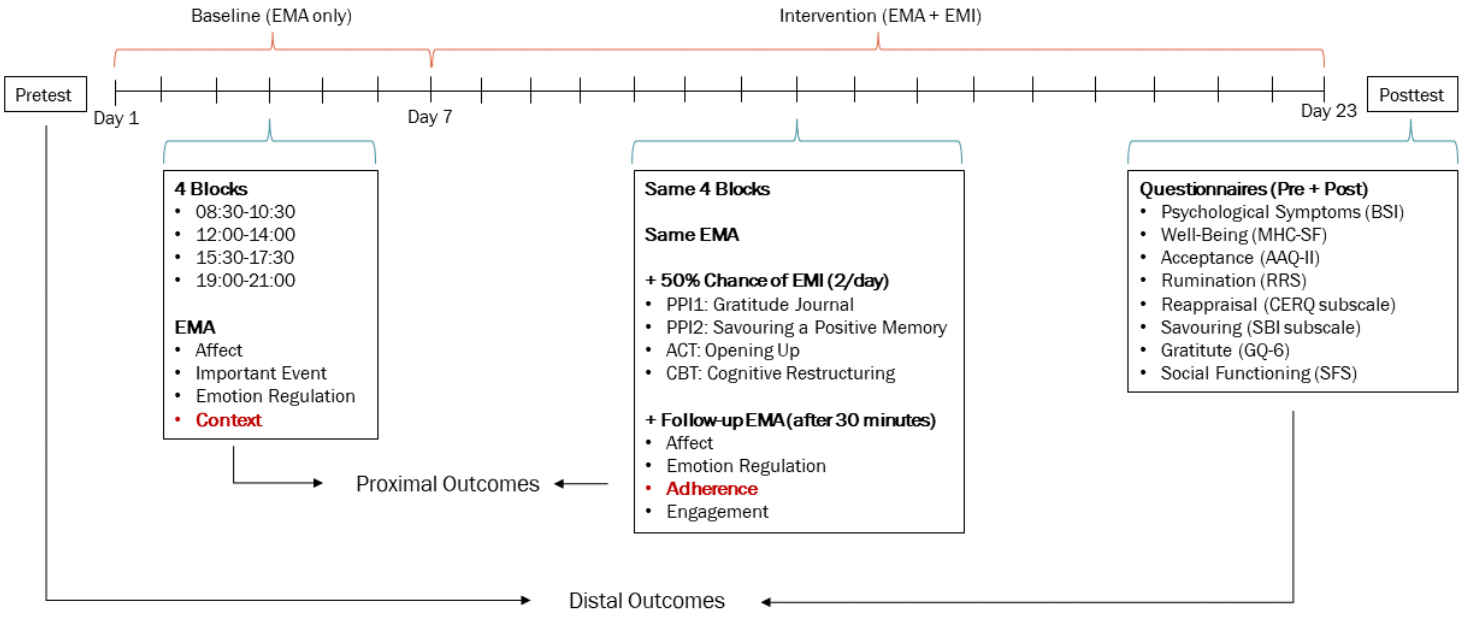
Design

Each participant followed a 23-day study period. During the first seven days, participants filled in four EMAs per day to establish baseline scores. EMAs were always the same and included 13 items. The following 16 days incorporated MRTs to assess EMI outcomes in natural context at the individual level (Bhide et al., 2018; Bidargaddi et al., 2020). MRTs also aid establishing causality (Klasnja et al., 2015), which is otherwise not possible in longitudinal daily life research without a randomised-controlled trial design. Every day during the 16-day MRT period, participants received four pre-EMAs followed by a post-EMA 30 minutes later. After each pre-EMA (64 in total), a MRT determined whether participants would

receive an EMI as well (Figure 1). EMIs were sent in 50% of all cases (32 in total) and always twice per day to ensure an equal distribution of EMIs across the 16-day period. The study included four different EMIs and participants received each EMI for four consecutive days to guarantee sufficient practice per EMI. To address possible sequence effects of the EMIs, an additional between-person randomisation was included in the study. Accordingly, participants were randomly allocated to two groups, which followed the four EMIs in reverse order across the 16-day MRT period (see pre-registration for details). The post-EMAs were included to determine proximal effects of the EMIs and included 10-12 items of which two were dependent on having received an EMI or not. In sum, participants could receive 156 EMAs and 32 EMIs over the entire 23-day study period.

Figure 1

Study Design



The study followed a semi-random sampling approach for two reasons. First, to ensure that participants cannot adjust to the study by expecting notifications at certain times as in fixed sampling, which would have undermined our understanding of momentary effects. Second, to

rule out the possibility of receiving notifications in short succession, which would be possible in random sampling but increase the study burden for participants. Thus, each day was separated into four blocks (08:30 – 10:30, 12:00 – 14:00, 15:30 – 17:30, 19:00 – 21:00) and included a randomly timed pre-EMA, followed by a MRT and a post-EMA 30 minutes later. The expiration time for EMAs and EMIs was 30-minutes.

EMIs

In total, four EMIs from different therapeutic traditions were included in the study (Figure 1; see pre-registration for details). During two positive psychological interventions (i.e. gratitude and savouring), participants tried to focus on positive things in their lives and reflect on them. In comparison, an exercise based on acceptance and commitment therapy (i.e. opening up), guided participants to try accepting negative thoughts and feelings without pushing them away. During the last exercise based on cognitive behavioural therapy (i.e. cognitive restructuring), participants tried to challenge their negative thoughts and test if they are true.

Measures

PA and NA, context, and adherence to EMIs were assessed through daily EMAs in the m-Path app. The specific items were designed with help of the ESM item repository (https://esmitemrepositoryinfo.com/), a database that can be searched for EMA items used in previous studies. In line with recommendations from previous research, EMAs were kept as short as possible (Eisele et al., 2022). An overview of the EMA items is provided in Table 1. Post-EMAs included the same measures for PA and NA, whereas context was not assessed again. If it followed an EMI, adherence was evaluated as well.

Table 1

Overview of EMA Items

Variable	EMA Item	Scale	Timing
Introduction	Welcome! The following questions will be about how you		

	felt just before you saw the notification for this questionnaire.		
NA	I felt stressed	1 (not at all) to 7 (very much)	Pre- & Post-EMA
	I felt down	1 (not at all) to 7 (very much)	Pre- & Post-EMA
PA	I felt cheerful	1 (not at all) to 7 (very much)	Pre- & Post-EMA
	I felt satisfied	1 (not at all) to 7 (very much)	Pre- & Post-EMA
	I felt that I have things in life to be thankful for	1 (not at all) to 7 (very much)	Pre- & Post-EMA
Social Company	Whom were you with?	1. Friend(s), 2. My partner, 3. My parent(s), 4. My child/children, 5. Other family member(s), 6. Colleague(s), 7. Peer(s), 8. Acquaintances, 9. Roommate(s), 10. Strangers, 11. People online, 12. Others, 13. Nobody.	Pre-EMA
Activity	What were you doing?	1. Nothing, 2. Resting, 3. Working/studying, 4. Eating/drinking, 5. Passive free-time (TV, computer, video games, reading), 6. Active free-time (walking, sports, gardening, going out), 7. Self-care, 8.Interacting/conversating, 9. Household chores/groceries,	Pre-EMA

		10. Mobile phone/social media, 11. Sleeping, 12. Something else.	
Location	Where were you?	1. At home, 2. At family/friend's place, 3. At work/school, 4. In restaurant/café, 5. Travelling (e.g., riding a train), 6. Nature, 7. Somewhere else inside, 8. Somewhere else outside.	Pre-EMA
Adherence	Did you do the exercise?	"Yes" or "No"	Post-EMA

Data Analysis

Data analyses were done in RStudio Ver. 2023.12.1+402 (RStudio Team, 2020) with multilevel mixed models to account for missing values and the nested data structure (Kraiss et al., 2023). Linear mixed effects regression (LMER) and generalised linear mixed effects regression (GLMER) analyses were performed with the lme4 package Ver. 1.1-33 (Bates et al., 2014) and results visualised with the ggplot2 package (Wickham, 2016).

Before running LMER analyses, overall, minimum and maximum adherence percentages were calculated. First, the dataset was filtered for moments in which participants received an EMI notification. Then, mean adherence percentages were calculated by generating the mean adherence for each participant and multiplying it by 100. Next, the overall adherence percentage was calculated by generating the adherence mean of all participants and multiplying it by 100. Finally, minimum and maximum adherence percentages were identified.

To analyse whether the effects of EMIs on PA and NA depend on context factors (i.e. current location, social company, activity), six moderation analyses were performed (Table 2).

In all models, *participant ID* was included as a random factor to account for the data structure nested within participants, which is typical for the repeated measures in MRTs. The moderation models did not control for PA and NA levels at Pre-EMA, which was done in additional sensitivity analyses. The dataset used for these analyses included moments in which participants received an EMI notification (EMI = 1) and moments in which they did not (EMI = 0) based on the MRT. The variables for these models were PA at Post-EMA, NA at Post-EMA, EMI (0; 1), colleague(s)/peer(s) (0 = being with others/alone; 1 = being with colleague(s)/peer(s)), work/school (0 = being elsewhere; 1 = being at work/school), working/studying (0 = other activity; 1 = working/studying). Based on the expectation that states of vulnerability and opportunity often occur in work-related contexts in distressed people (Viertiö et al., 2021; Anderson et al., 2014), the variables colleague(s)/peer(s) (social company), work/school (current location), and working/studying (activity) were created during data preparation based on the data from context EMA items (Table 1).

Table 2

LMER Models for Research Question 1

Model	Outcome	Variable 1	Variable 2	Interaction	Random Effect
1	PA	EMI	Colleague(s)/ Peer(s)	EMI * Colleague(s)/ Peer(s)	ID
2	PA	EMI	Work/School	EMI * Work/School	ID
3	PA	EMI	Working/Studying	EMI * Working/Studying	ID
4	NA	EMI	Colleague(s)/ Peer(s)	EMI * Colleague(s)/ Peer(s)	ID
5	NA	EMI	Work/School	EMI * Work/School	ID
6	NA	EMI	Working/Studying	EMI * Working/Studying	ID

To evaluate whether adherence to EMIs is influenced by context factors (i.e. current location, social company, activity) three GLMER analyses were run. Again, all models included *participant ID* as random factor. In contrast to the moderation analyses above, the dataset used for these analyses only included moments in which participants received an EMI notification (EMI = 1). All models included adherence (0 = did not follow EMI; 1 = did follow EMI) as the outcome variable and one of the context factors alone (0 = with others; 1 = alone), home (0 = elsewhere; 1 = in home environment), and passive (0 = being active; 1 = being passive) as predictor. Based on the expectation that participants are more receptive in these contexts because they can easily receive, process, and use the provided EMI, the context variables were created during data preparation based on the data from context EMA items (Table 1).

In addition to the main analyses, sensitivity analyses were performed to see whether participant compliance with the study protocol would affect the results. A 30% threshold for completed EMAs was deemed insufficiently informative, as it would have excluded only a small part of the data from three participants. Consequently, a 50% threshold was chosen, resulting in the exclusion of nine participants. Afterwards, all the main analyses outlined above were repeated. Since PA and NA were assessed at Pre- and Post-EMA, further sensitivity analyses were run to control for the influence of Pre-EMA PA and NA scores, which were included in the six moderation models as an additional covariate.

Lastly, the different EMIs were compared with each other in exploratory analyses to identify differences in terms of effectiveness depending on the context. Therefore, the original data was split per EMI type (gratitude, savouring, opening up, cognitive restructuring) into four new datasets. Then, analyses for the six moderation models were repeated per EMI type.

Results

Sample Characteristics

The sample included 72 participants (48 female, M_{age} = 22.90, SD_{age} = 3.66). Most of them were students (41) or working students (18) and had German (24) or Dutch nationality (19). The average response rate to EMAs was 71.80% (range 18.59% - 99.36%), and average adherence to EMIs was 61.20% (range 6.25% - 100%).

Effects of Context on EMI Effectiveness

The results for receiving an EMI in different contexts (i.e. being with colleague(s)/peer(s), being at work/school and working/studying) and the effects on PA and NA are summarised in Table 3 and visualised in Figures 2 and 3. First, being with colleague(s)/peer(s) did not significantly moderate the effect of receiving an EMI on PA, $t(2740) = .983$, $p = .326$, and NA, $t(2740) = 1.257$, $p = .209$. Second, being at work/school did not significantly moderate the effect of receiving an EMI on PA, $t(2735) = .002$, $p = .998$, and NA, $t(2736) = -.413$, $p = .680$. Third, working/studying did not significantly moderate the effect of receiving an EMI on PA, $t(2730) = 1.047$, $p = .295$, and NA, $t(2731) = -.753$, $p = .452$.

Table 3

Results of the LMER Models for PA and NA Outcomes at Post-EMA

Model	Interaction	Outcome	Estimate	Std. Error	Degrees of Freedom	*t*-value	*p*-value
1	EMI *	PA	.158	.160	2740.385	.983	.326
2	Colleague(s)/Peer(s)	NA	-.239	.190	2740.623	-1.257	.209
3	EMI *	PA	<.001	.108	2735.757	.002	.998
4	Work/School	NA	-.053	.128	2736.168	-.413	.680
5	EMI *	PA	.090	.087	2730.839	1.047	.295
6	Working/Studying	NA	-.077	.102	2731.112	-.753	.452

Figure 2

Barplot of the Interaction Between Receiving an EMI Notification (Right) or not (Left) and Context Factors Company (Blue), Location (Orange), and Activity (Yellow) on PA Outcomes at Post-EMA (Y-Axis)

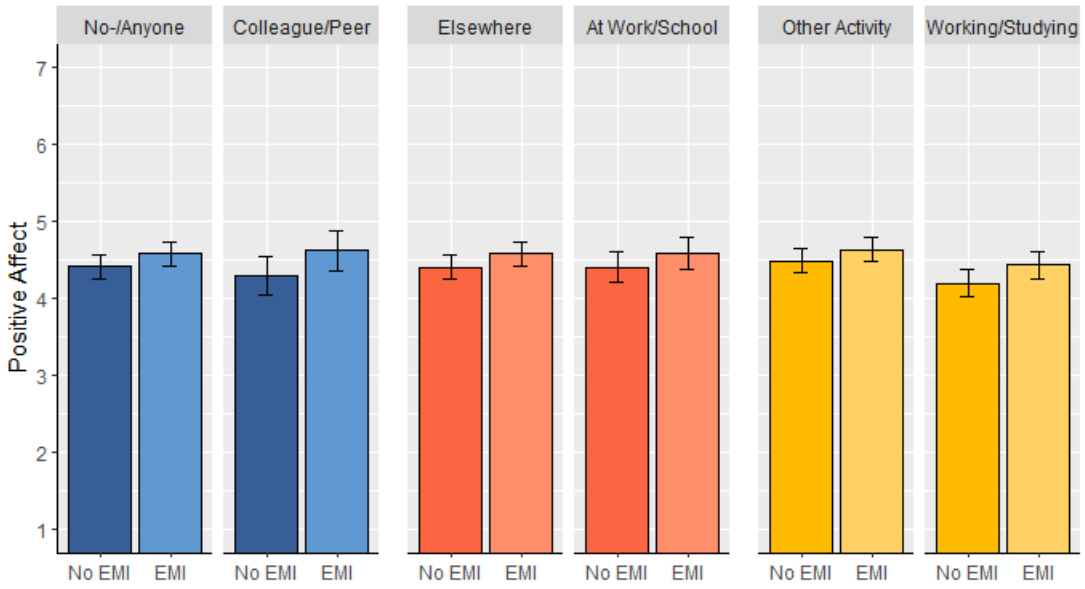
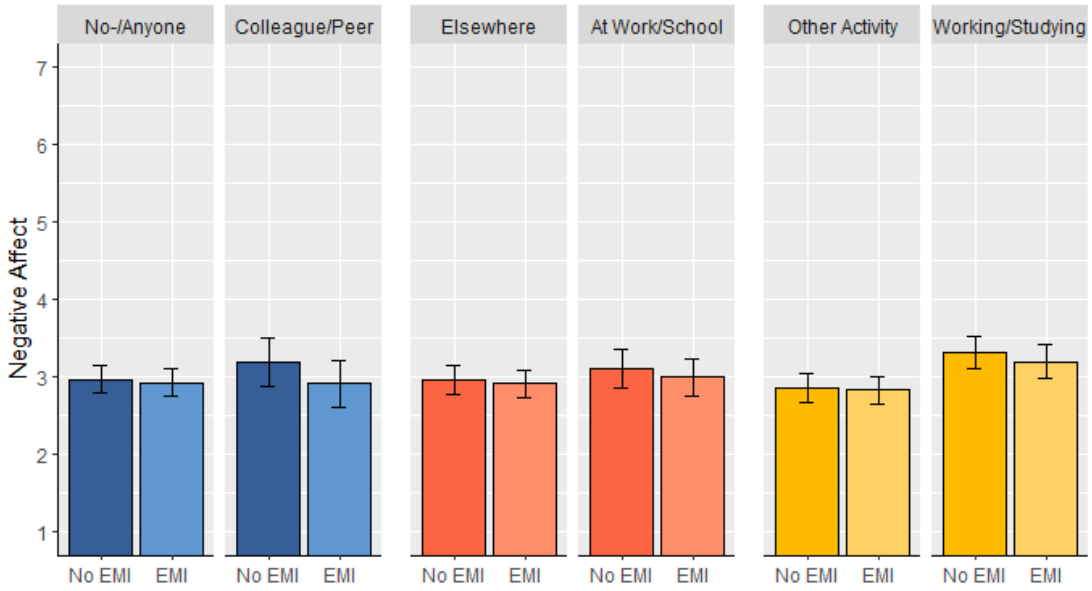


Figure 3

Barplot of the Interaction Between Receiving an EMI Notification (Right) or not (Left) and Contextual Factors Company (Blue), Location (Orange), and Activity (Yellow) on NA Outcomes at Post-EMA (Y-Axis)



Effects of Context on EMI Adherence

Table 4 summarises and Figure 4 visualises the results for the influence of contextual factors (i.e. being alone, being in a home environment and being passive) on adherence to EMIs. First, the results showed that being alone when receiving an EMI was not significantly related to EMI adherence, b_{alone} = .160, z = 1.213, p = .225. Second, receiving an EMI while being in a home environment was significantly associated with EMI adherence, b_{home} = 1.712, z = 15.317, p <.001. Third, receiving an EMI while being passive was significantly related to EMI adherence, $b_{passive}$ = 1.258, z = 9.955, p <.001.

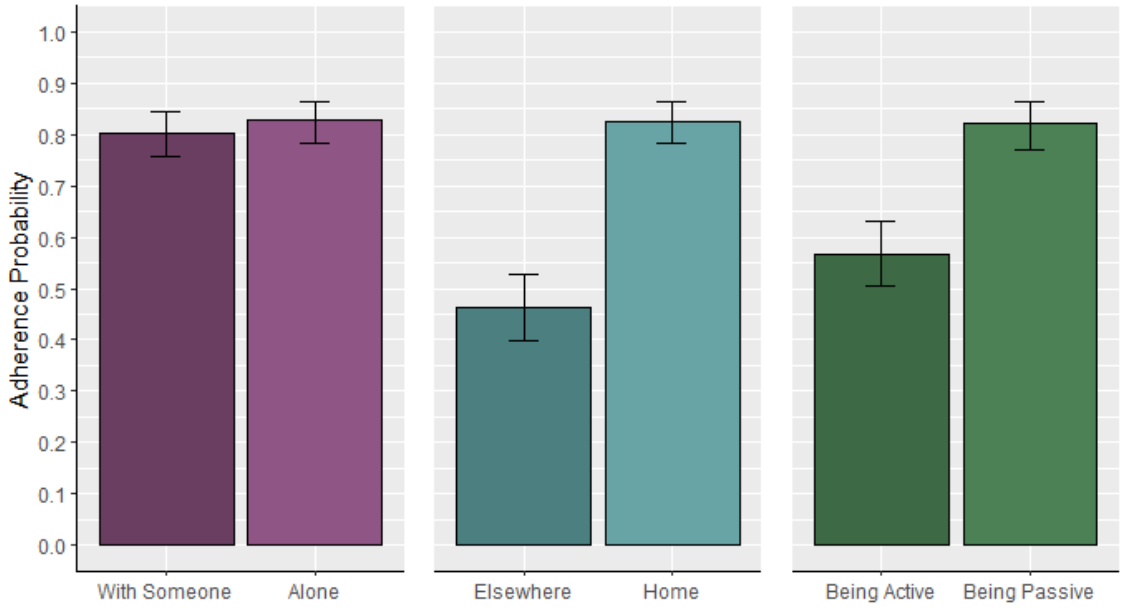
Table 4

Results of GLMER Models for Adherence to EMIs

Model	Predictor	Outcome	Estimate *b*	Std. Error	*z*-value	*p*-value
1	Being Alone	Adherence	.160	.132	1.213	.225
2	Being Home		1.712	.112	15.317	<.001***
3	Being Passive		1.258	.126	9.955	<.001***

Figure 4

Barplot of the Context Factors Company (Purple), Location (Blue), and Activity (Green) and Their Association with EMI Adherence Probability



Sensitivity Analyses

To determine whether the commitment of participants to the study affected the results, additional sensitivity analyses were performed. Results of these analyses did not lead to different conclusions compared to the original analyses. Furthermore, controlling for Pre-EMA PA and NA scores in the original moderation models, generally led to similar conclusions in comparison to the main results (Table 3). As an exception, working/studying did significantly moderate the effect of receiving an EMI on PA when controlling for Pre-EMA PA scores, $t(2739) = 2.221$, $p = .026$.

Exploratory Analyses

In additional exploratory analyses, the different EMIs were compared with each other to understand if one was more effective than the others in certain contexts. In general, the results reflected the findings of the original moderation analyses. As an exception, working/studying significantly moderated the effect of receiving an 'opening up' EMI, leading to a reduction in NA, $t(625) = -2.253$, $p = .025$. Besides EMI effectiveness, adherence was also explored per EMI type in different contexts. The findings aligned with the original analyses as the results remained the same when differentiating between EMI types.

Discussion

The research objective of the present study focused on investigating the influence of context factors on EMI effectiveness and adherence. The results showed that being with colleague(s)/peer(s) (social company), being at work/school (current location), and working/studying (activity) did not significantly moderate the effect of EMIs on PA and NA. Furthermore, being home (current location) and being passive (activity) were significantly related to EMI adherence. While adherence to EMIs did not significantly differ when being alone compared to being with someone else (social company), adherence probabilities in these contexts were comparable to being home and being passive.

Context and EMI Effectiveness

As context factors did not significantly moderate the effect of EMIs on mental health outcomes, it could be questioned whether it is worthwhile to tailor EMIs to context as previous research has suggested (De Vries et al., 2021; Dao et al., 2021; Kwasnicka et al., 2016; Conner & Norman, 2017; Müller-Riemenschneider et al., 2008). Specifically, earlier studies have highlighted the importance of states of vulnerability and opportunity for the effectiveness of EMIs (Nahum-Shani et al., 2015), that were considered in the present study by analysing the effectiveness of EMIs in work-related contexts which are often linked to psychological distress (Viertiö et al., 2021; Anderson et al., 2014).

One possible reason for the non-significant findings could be the broad level at which context was captured. Context was measured four times per day to identify general contexts and their connection to EMIs and mental health outcomes. However, providing EMIs might require a more fine-grained approach. For instance, even if distress is often linked to work-related factors (Viertiö et al., 2021; Anderson et al., 2014), not all aspects of work induce distress, and individuals are not constantly under psychological distress when working or studying. In fact, work can also instil a sense of satisfaction or purpose in people or simply be

fun and enjoyable (Viertiö et al., 2021). Yet, different individuals may be vulnerable at different times (Ebner & Singewald, 2017), such as before meetings or during tight project deadlines, even within the same work-related context (e.g., same office, colleagues, and work). In other words, different individuals could benefit from EMIs in different moments even if they are in the same general context. Therefore, individual differences might play an important role for the effectiveness of EMIs and context needs to be considered on a more individualised level such as where am I working (office, home, meeting room etc.), with whom am I working (alone, friend, colleague A, colleague B, boss, customers etc.), what am I working on (presentation, meeting notes, proposal, recruiting etc.).

Next to between-person differences, within-person differences could also influence EMI effectiveness. Since distress varies within people (Wang et al., 2020; Sliwinski et al., 2009), an individual may be vulnerable in a specific context (e.g., working with a difficult colleague) on one day but not on another, even if the context remains the same. Thus, the same individual might benefit from an EMI on one day but not on the next. While there could be many reasons for this, the sole consideration of context to determine whether a person is in a state of vulnerability and opportunity reaches its limits in such cases, which could be an additional reason for the non-significant results.

Furthermore, individual behaviour and context substantially fluctuate over the course of a day (De Vries et al., 2021; Dao et al., 2021; Kwasnicka et al., 2016; Conner & Norman, 2017) and even small changes in context can make a difference in terms of distress, vulnerability, and opportunity. For example, a person might be comfortable during a meeting but become distressed once their boss enters the room. As outlined above, context was assessed four times per day in this study to generally understand contextual influences on EMIs and mental health outcomes. However, depending on the goal of the EMI, it might be necessary to

capture context on the hourly or even minute level to identify states of vulnerability and opportunity and thereby ensure EMI effectiveness (Nahum-Shani et al., 2015).

In this study, context has been treated as a uniform concept that is closely linked to vulnerability and opportunity. However, it might be necessary to differentiate between the context that is linked to the cause of psychological distress and the context in which a person is in a state of vulnerability and opportunity. For example, an individual might be in distress for work-related reasons but be able to adaptively cope during the day. Yet, when the individual arrives at home in the evening, they might become vulnerable (e.g., due to excessive rumination about work) and benefit from an EMI. Consequently, context is important for the timing of an EMI, and needs to be differentiated from the context causing the distress. However, this study only assessed the effectiveness of EMIs in relation to the momentary context right before the EMI was provided, which might not have been concurrent to states of vulnerability and opportunity.

Despite the finding that context did not moderate the effectiveness of EMIs in this study, it cannot be concluded that tailoring EMIs to context is ineffective. The discussion suggests that a more nuanced approach is needed, considering individual and within-person differences, context fluctuations, and the timing of EMIs. Future research should focus on a more detailed assessment of context, particularly in relation to specific mental health problems such as work-related distress.

Lastly, EMI effectiveness likely depends on a complex interplay of factors not limited to context. For example, the design of EMIs is important and must be evidence-based, attractive, and tailored to user's needs (Laure et al., 2023; Van Gemert-Pijnen et al., 2011; Lattie et al., 2019). Next, psychological factors, such as the level of distress a person experiences, may also play a crucial role (Ye et al., 2018; McKay et al., 2014). For instance, EMIs might be more effective when provided in moments of high psychological distress (Perski et al., 2022).

However, detection of these states of vulnerability and opportunity might require a more continuous assessment of distress that is not limited to a few moments per day to increase EMI effectiveness. As an alternative, capturing physiological data with additional wearable sensors (e.g., chest band with electrodes assessing electrocardiography and respiration) might be considered (Yang et al., 2023). In fact, electrocardiography and respiration data is sufficient to reliably detect NA (Yang et al., 2023). Indeed, collecting physiological data is less obtrusive and decreases the reporting burden for participants eliminating the necessity to fill in EMAs eight times per day as in the current study. Taken together, future studies need to consider which EMI design aspects and psychological states are relevant for the effectiveness of EMIs and how psychological states can be detected by means of EMAs and physiological data.

Context and EMI Adherence

The study found that being in a home environment and being passive were significantly related to EMI adherence, which suggests that people were more receptive to EMIs in these contexts. It can be concluded that being in a home environment and being passive are contexts in which people should be provided with EMIs to increase adherence. However, for EMIs to be truly effective, individuals need to be in states of receptivity and states of vulnerability and opportunity at the same time (Nahum-Shani et al., 2015). While the results indicate that people are generally more receptive to EMIs in home environments, there might be between-person differences in how receptivity, vulnerability, and opportunity align. For example, one individual might experience heightened distress when arriving at home after a stressful day at work, which would mean that receptivity, vulnerability, and opportunity co-occur, and an EMI should be provided. Conversely, another individual might feel safe and relaxed at home after a challenging day, meaning they are not in a state of vulnerability and opportunity. Maybe this individual would have benefitted from an EMI at work but was not receptive at that time.

Conclusively, EMIs should not always and not exclusively be provided in home environments, only if states of receptivity, vulnerability and opportunity align in this context.

Even though home environments are generally a favourable context for being receptive to EMIs, states of receptivity might arise in different locations (Künzler et al., 2019). The results showed higher adherence during passive activities such as resting, watching TV, using a computer, playing video games, reading, and using social media. These activities share that they are not very demanding, and user's might therefore be receptive to them (Pielot et al., 2017). This suggests that people might also be receptive to EMIs during low-demand tasks at work, or during breaks when they engage in passive activities like using their smartphone. Further research is needed to confirm these ideas and to explore which factors determine states of receptivity.

Interestingly, the study did not find significant differences in adherence between being alone and being with others. This raises the question if EMIs can be provided to people in any social context. However, it is important to distinguish between EMI adherence and engagement (Pielot et al., 2017). Even though adherence to EMIs was similar when having company or not, being with others might negatively affect the quality of the interaction with the EMI. Possibly, participants take less time to complete the EMI, are interrupted in between, or do not concentrate on the EMI as much. In that regard, previous research has found an association between greater engagement to a mindfulness EMI and increased PA (Pavlacic et al., 2022). Since the current study cannot confirm these findings, further research about the influence of engagement on EMI effectiveness is warranted. Besides quantitative longitudinal studies, qualitative interview studies could be feasible for the identification of factors and mechanisms that drive engagement with EMIs.

In conclusion, it is generally feasible to provide EMIs to people when they are at home and during passive activities to take advantage of the increased adherence probabilities.

However, individual differences need to be considered to provide EMIs in contexts where states of receptivity, vulnerability and opportunity align. Additionally, further research is necessary to understand the exact nature of passive activities and how they facilitate receptivity to EMIs. Finally, more studies are required to investigate the relationship between context and engagement with EMIs to optimise their delivery and effectiveness.

Strengths and Limitations

A central strength of this study is the use of MRTs to deliver EMIs, enabling causal and temporal conclusions in contrast to intensive longitudinal studies that only permit correlational observations (Klasnja et al., 2015; Kuppens & Myin-Germeys, 2021). Furthermore, the study incorporated four EMIs based on different therapeutic approaches, unlike previous studies that mainly focused on single EMIs only (Balaskas et al., 2021). While no difference between the EMIs in terms of effectiveness and adherence in different contexts was found, understanding which EMIs work best in daily life is central for developing evidence-based EMIs promoting mental health.

Nevertheless, the current findings should be interpreted under consideration of some limitations. First, the results are not generalisable to other populations since most participants were students or working students. Second, the present study was not powered for moderation analyses. This limitation applies to the adherence analyses as well because only cases where participants received an EMI were included. Hence, the risk of type II errors is increased as true effects might not have been detected. Third, the analyses conducted focused on momentary mental health outcomes only and changes in long-term mental health outcomes were not investigated. Thus, no conclusions about the influence of adherence or effectiveness on long-term mental health outcomes can be drawn based on the results.

Conclusion

The present study investigated the influence of context factors on EMI effectiveness and adherence in promoting mental health. While context did not moderate EMI effectiveness, it cannot be concluded that tailoring EMIs to context is ineffective. A more nuanced assessment of context is needed, considering individual and within-person differences, context fluctuations, and timing. Adherence was higher at home and during passive activities, indicating these as feasible contexts for EMI delivery. However, EMIs should be provided in contexts where states of receptivity, vulnerability and opportunity align on the individual level. Finally, the nature of passive activities and engagement with EMIs require further research to enhance receptivity and EMI effectiveness.

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