Investigating the Momentary Effects of Positive Psychology Interventions in Addressing Mental Health: A Micro-Randomised Trial Study

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Bachelor Thesis

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Abstract

Background: Mental health challenges are prevalent worldwide, leading to struggling health care. Positive Psychology Interventions (PPIs), delivered through mHealth, demonstrate an accessible and promising solution. This study examines the proximal effect of PPIs on the positive and negative affect by applying micro-randomised trials (MRTs). This study further investigates mental health changes after participating in PPIs for 15 days. The secondary objective is to evaluate the acceptance and feasibility of the research method of MRTs in assessing PPIs' proximal effects.

Methods: A non-probability sample (N = 28) was recruited for a 15-day MRT study. Participants engaged with PPIs delivered as micro-interventions and completed ecological momentary assessments through the app m-path. Before and after the participation in the intervention, the participant's mental health was examined by measuring their overall well-being and anxiety and depression symptoms. An acceptance questionnaire assessed the MRTs' acceptance and feasibility.

Results: PPIs significantly enhanced positive ($p = .02$) and reduced negative affect ($p = .03$) in close proximity to participation. Distal mental health outcomes significantly increased by enhanced well-being ($p = .02$) and reduced anxiety ($p < .01$) and depression symptoms ($p = .03$). Participants reported high acceptance of study materials, moderate burden and positive mental health outcomes.

Conclusion: This thesis demonstrated PPIs' positive proximal effect in improving affect and PPIs' positive distal effect in improving overall mental health over a 15-day intervention. MRTs were acceptable and feasible in measuring proximal outcomes and supported their integration into Just-in-time Adaptive interventions (JITAIs). Despite limitations regarding the sample size and diversity, this study underscores the value of mHealth interventions and suggests the application of PPIs as mHealth intervention components.

Investigating the Momentary Effects of Positive Psychology Interventions in Addressing Mental Health: A Micro-Randomised Trial Study

Over 300 million people (4.4 % of the world's population) are estimated to suffer from depression, and the numbers are constantly increasing (World Health Organization, 2017). Health systems struggle under the burden of widespread mental health problems, leading to both constrained accessibility and availability of health services (Bidargaddi et al., 2020). As a consequence, individuals suffering from mental health issues increasingly turn to self-help activities like Mobile Health (mHealth) interventions. mHealth interventions have become increasingly valuable for sustainably supporting mental health (McKechnie et al., 2023). They deliver exercises, text messages from an app or SMS prompting tasks, medication reminders, and help monitoring well-being (Bidargaddi et al., 2020; Carrandi et al., 2023; McKechnie et al., 2023; Walton et al., 2018). Given the dynamic and complex nature of underlying psychological processes influenced by diverse factors such as an individual's environment, strengths, and health states, developing supportive exercises requires extensive research to ensure mental health benefits for individuals (Silva et al., 2015).

Promising exercises delivered through mHealth interventions are Positive Psychology Interventions (PPIs), defined as therapeutic or self-help activities and practices designed to enhance well-being, promote positive emotions, and improve overall mental health (Sin & Lyubomirsky, 2009). PPIs complement traditional therapy by effectively improving mood and well-being, empowering character strengths and self-development, encouraging the development of relationships and creating meaning and purpose in individuals life (Bolier et al., 2013; Mongrain & Anselmo-Matthews, 2012; Seligman et al., 2005; Sin & Lyubomirsky, 2009). Evidence by meta-analyses conducted by Chakhssi et al. (2018) resulting in moderate

effect sizes indicates PPIs' potential to improve well-being and alleviate mental health issues. However, further evaluation of PPIs in affecting mental health outcomes is inevitable.

The golden standard for examining the effectiveness of interventions is the Randomised Control Trial (RCT), a research design involving the random allocation of participants to intervention and control groups to assess the causal impact of experimental manipulations on potential outcomes (Austin, 2011; Bondemark & Ruf, 2015; Schulz et al., 2010). For example, in a meta-analysis of several studies using PPIs delivered as RCTs, Bolier (2013) found moderate effect sizes of PPIs in influencing well-being on a group level. Although RCTs are primarily used for examining psychological interventions, they have fundamental shortcomings in (1) measuring momentary outcomes of intervention components, (2) considering natural conditions (contexts) and (3) measuring the effectiveness on an individual level (Bhide et al., 2018; Bidargaddi et al., 2020; Bhide et al., 2018; Chakhssi et al., 2018).

An innovative research method that can overcome these limitations is Micro-Randomised Trials (MRTs), which deliver intervention components multiple times a day/week, impacting distal (long-term) outcomes through momentary proximal outcomes (Walton et al., 2018). Unlike RCTs, MRTs function as factorial designs, optimising interventions by (within-person) repeated measures that evaluate individual treatment components and guiding decisions on component elimination and delivery contexts (Luers et al., 2019; (Walton et al., 2018). While RCTs randomise participants into treatment groups at the study's onset, MRTs randomise treatments at a micro-level, focusing on individual moments within a participant's life rather than solely focusing on long-term outcomes on a group level (Bhide et al., 2018). Consequently, MRTs offer a more detailed understanding of the influence of individual units on participants, providing real-time momentary information

in a natural environment while still measuring long-term outcomes (Bidargaddi et al., 2020; Klasnja et al., 2015).

The examination of PPIs effectiveness applied by MRTs contains (1) the delivery of PPIs through Ecological Momentary Interventions (EMIs) and (2) the assessment of momentary outcomes through Ecological Momentary Assessments (EMAs). EMIs are interventions provided to participants during everyday life and in natural settings (Heron & Smyth, 2010). The EMAs repeatedly assess the participants' momentary experiences and feelings close to the delivered treatment, measuring the momentary influence of PPIs on an individual level (Shiffman et al., 2008; Stone & Shiffman, 1994; Trull & Ebner-Priemer, 2009). Incorporating EMIs and EMAs into the design of MRTs helps assess the individual outcomes in close proximity to individual intervention components.

In summary, mHealth is the new edge of healthcare innovation and builds a solution for the high demand for therapy and health services. PPIs are commonly used to provide self-help activities focused on well-being and applicable outside a therapy room. Since the underlying psychological processes are dynamic and complex, mHealth requires constant attention and ongoing research. PPIs are promising as effective intervention units for improving mental health. Recent research predominantly examined mHealth interventions using PPIs through RCTs, emphasising long-term outcomes without addressing PPIs' momentary effects. The innovative study design of MRTs should help overcome the limitations of the commonly used RCTs by comparing group effects on proximal rather than solely focusing on distal outcomes. By employing the study design of MRTs, this study aims to make a first attempt to investigate both the short-term (proximal) and long-term (distal) effects of PPIs on mental health. Additionally, the MRT as a research method for examining PPIs' effectiveness will be evaluated based on its pioneering application in this study. Specifically, this study seeks to answer three primary research questions:

1. What are the proximal effects of PPIs delivered as EMIs on positive and negative affect?
2. How do these interventions impact the distal outcomes of well-being and depressive and anxiety symptoms?
3. How feasible and acceptable is the method of micro-randomised trials as a research design studying PPIs?

The primary hypothesis is that incorporating PPIs into mHealth interventions will result in immediate mood improvements, characterised by increased positive affect (PA) and reduced negative affect (NA). Secondly, it is proposed that prolonged exposure to these interventions will positively influence long-term mental health outcomes induced by increased well-being and reduced depressive and anxiety symptoms. Lastly, it is hypothesised that the innovative approach of MRTs is feasible and applicable for assessing the impact of PPIs, enabling efficient measurement of their effects.

Method

Participants

A non-probability sample recruited via convenience sampling completed the baseline and post-questionnaire (N=28). Convenience sampling recruits readily available participants for whom the study was easily accessible. Participants were recruited via shared links provided on various social media platforms. Additionally, students of the University of Twente who participated could enter the study via the university's internal research platform, SONA. Students gained four SONA credits by signing in and completing the study via SONA. Inclusion criteria to participate were (1) to be at least 18 years of age and (2) to possess a sufficient English level. Participants also required a smartphone to use the study material.

Materials

Baseline & Post questionnaire

This study measured the distal mental health outcomes by assessing the participants' overall mental health at two different time points: (1) before and (2) after the intervention. At the first assessment point, the baseline questionnaire assessed the Mental Health Continuum – Short Form (MHC-SF), the Patient Health Questionnaire – 9 (PHQ-9) and the General Anxiety Disorder – 7 (GAD-7). At the second assessment point, the post-questionnaire assessed the same tests as the baseline questionnaire but also answered an acceptance questionnaire, which examined the study methods' acceptance and feasibility.

The MHC-SF measures mental health on 14 items (Appendix 1), with response options indicating how frequently individuals reported symptoms of social, psychological, and emotional well-being (Lamers et al., 2011). On a 6-point Likert (never – once or twice a month – about once a week – two or three times a week – almost every day – every day), the participant rates the frequency of each symptom. The successive scores are summed, ranging from 0 to 70, with higher numbers indicating positive well-being and lower scores indicating negative well-being. In several Dutch studies, the MHC-SF showed good psychometric properties (Lamers et al., 2011). This study's test data showed a Cronbach's Alpha of 0.92, indicating excellent internal consistency.

The PHQ-9 is a healthcare instrument that assesses the intensity of participants' depressive symptoms (Kroenke et al., 2001). Participants rated the frequency of nine depressive symptoms (Appendix 2), such as exhaustion or weight loss, on a four-point scale (not at all – several days – more than half the days – nearly every day). The resulting summed scores ranged from 0 to 27, with higher scores indicating symptoms of a severe depressive disorder and lower scores indicating no present type of depressive disease. The PHQ-9 is a robust and reliable measure for assessing depression symptoms in individuals (Kroenke et al.,

2001). This study's test data had a Cronbach's Alpha of 0.81, suggesting good internal consistency.

The GAD-7 is a measurement tool assessing the severity of generalised anxiety disorder (GAD) symptoms in participants by employing seven items (Appendix 3) describing GAD-manifested symptoms (Spitzer et al., 2006). On a four-point scale (not at all – several days – more than half of the days – nearly every day), participants rate the frequency of these items (Spitzer et al., 2006). The successive scores are added together and range from 0 to 28, with higher scores suggesting more severe GAD symptoms and lower levels indicating milder GAD symptoms. The GAD-7 showed good psychometric properties in an American sample (Spitzer et al., 2006). This study's test data showed a Cronbach's Alpha of 0.92, indicating excellent internal consistency.

In addition to assessing the participant's mental health, an acceptance questionnaire assessed the overall acceptance and feasibility of the study method on 19 items retrieved from a Dutch experience sampling method study by Eisele et al. (2020). The acceptance questionnaire was part of the post-assessment after the study period and focused on the study's assessment components, micro-interventions, the participants' motivation, perceived burden, clarity of instructions, and overall experience with working with the app. A table of all items is provided in Appendix 4.

EMAs

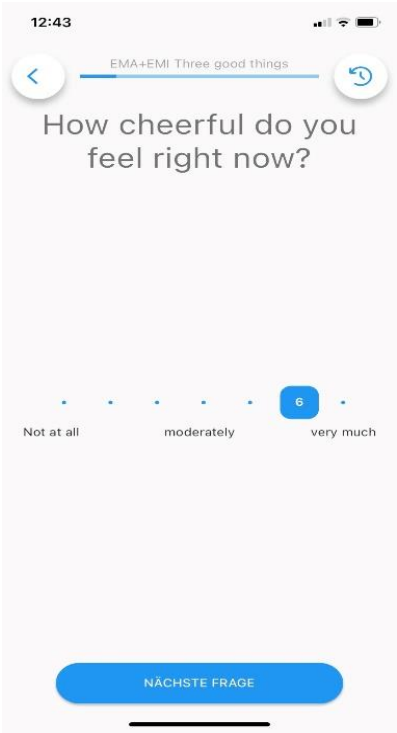
EMAs assessed the proximal outcomes by addressing the participants' affect. The PA was assessed by asking the participant *How cheerful, enthusiastic, satisfied and relaxed do you feel right now?.* The NA was assessed by asking the participant *How anxious, irritable, sad and down do you feel right now?.* Participants could answer on a 7-point Likert scale ranging from *Not at all* to *Very much*. An overview of all items is provided in Appendix 5. The items were retrieved from the Positive and Negative Affect Schedule (PANAS), which

assesses negative and positive emotional states and has shown good psychometric properties in several clinical samples (Crawford & Henry, 2004; Matthys et al., 2021; Thompson, 2007; Watson et al., 1988). Although PA and NA are separate yet correlated constructs, a two-factor model is supported in several studies that examined the psychometric properties of the PANAS (Tuccitto et al., 2009; Watson et al., 1988).

The EMAs were delivered via m-path, a platform to provide assessments and treatments in everyday life via mobile devices (KU Leuven, 2020). Via the m-path app, participants received the EMAs on their smartphones, providing real-time data and insights into contexts of participation. Figure 1 visualises an example item, assessing the PA by (1) asking the participant a question and (2) allowing the participant to answer by moving the cursor on a scale from 1 to 7.

Figure 1

Screenshot of an example item of the EMAs applied in M-Path



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Micro-interventions as EMIs

As an intervention unit, participants participated in five selected micro-interventions delivered as EMIs. Participants participated in the same micro-intervention for three consecutive days before starting the next one, so there was the chance to work with every micro-intervention for three days overall. The micro-interventions consisted of five PPIs, which were selected based on prior research that found these PPIs to be effective in increasing PA and fostering well-being (Emmons & McCullough, 2003; Klibert et al., 2022; Lai, 2017; Otsuka et al., 2012; Schutte & Malouff, 2019). The PPIs covered the positive psychological areas of *Three good things*, *Gratitude journaling*, *Positive memory*, *Personal strengths* and *Express gratitude*. Table 1 provides an overview of the PPIs, their time frames, descriptions and literature references. Figure 1 shows a screenshot of an example PPI delivered in the m-path app. The structure of all PPIs was similar: (1) reading the descriptions of the daily task, (2) reading the instructions of the daily task, and (3) performing a task and reflecting on a task by writing into the text box or using a separate writing utensil.

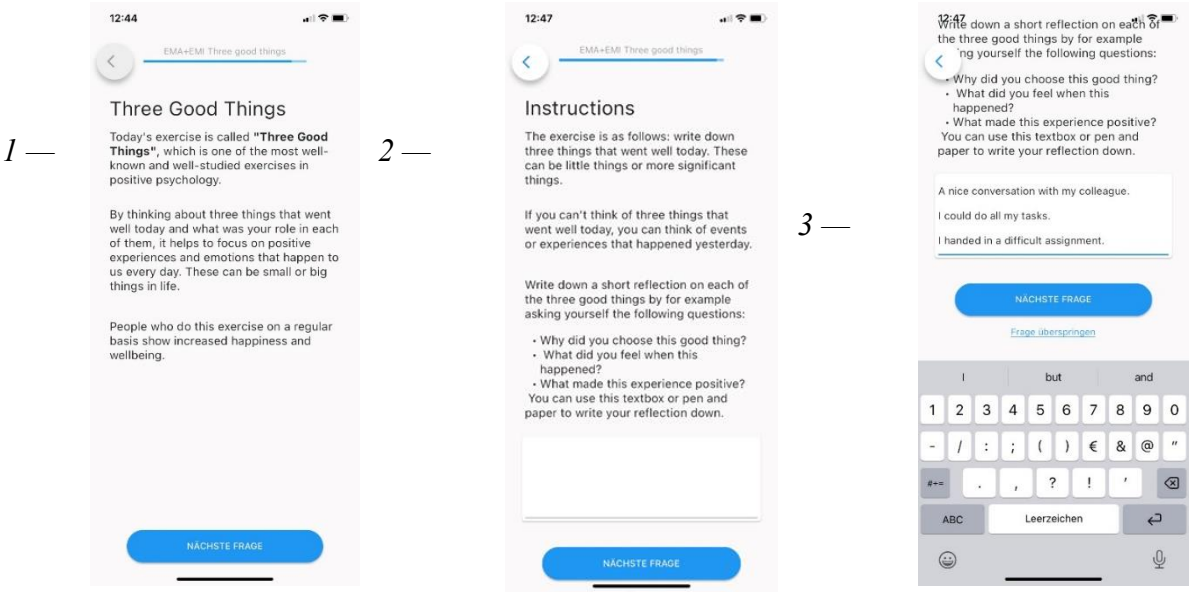
Table 1

Overview of the selected PPIs

PPI	Days	Description	First author, year
		Participants were asked to…	
Three good things	1 – 3	…describe and reflect on three good things of the day before.	Lai, 2017
Gratitude journaling	4 – 6	… name and reflect on three people or events they are grateful for.	Emmons & McCullough, 2003; Otsuka et al., 2012
Positive memory	6 – 9	… describe and reflect on a positive memory.	Klibert et al., 2022
Personal strengths	9 – 12	… choose one of three character strengths most fitting to them, and do a strength-related task.	Schutte & Malouff, 2019; Seligman, 2002; VIA Institute on Character, 2023
Express gratitude	12 – 15	… express their gratitude to someone they are grateful for.	Emmons & McCullough, 2003; Otsuka et al., 2012

Figure 2

Screenshot of EMI applied in M-Path (German version). 1. Description; 2. Instruction; 3. Answer box.



Procedure & Design

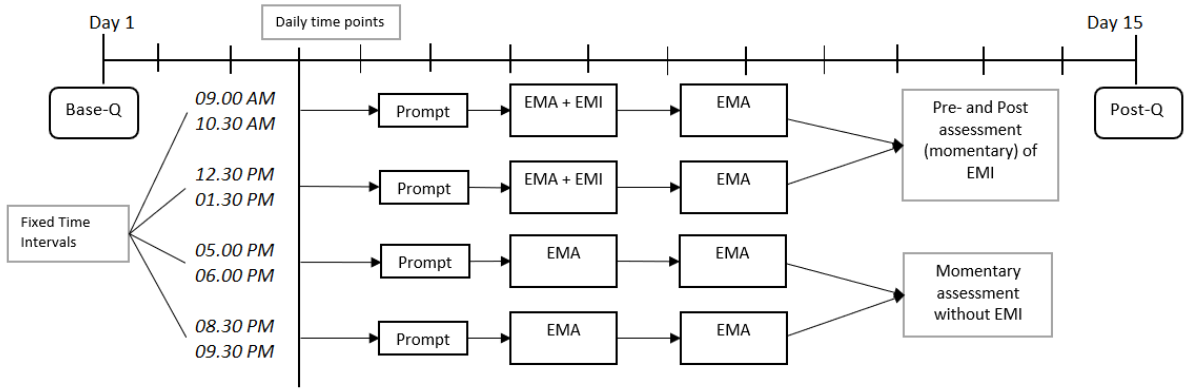
The study was reviewed and approved by the Ethics Committee of the Behavioural, Management, and Social Sciences of the University of Twente (Request nr.: 231221), and data was collected from 01/11/23 to 30/11/23. Via their mobile device, participants received a link to a Qualtrics survey where active informed consent was provided, and instructions on the study, app download, and baseline questionnaire were given. After consenting to participate and answering the baseline questionnaire, participants downloaded the app m-path (supplied in the Apple App Store or Google Play Store) and registered themselves with a code for this study.

Following the baseline questionnaire, with the aim to assess proximal affect outcomes of the PPIs, participants started the 15-day MRT with m-path. Within this MRT, this study used a time-contingent sampling method (de Vries et al., 2021) with up to eight notifications each day during four predefined time intervals from *9:30 to 10:30 am (morning), 12:30 to 1:30 pm (midday), 5 to 6 pm (afternoon) and 8:30 to 9:30 pm (evening)*. At a random time point during each interval, participants were requested to complete two EMAs, and with a probability of 50 %, to participate in one micro-intervention provided as EMI. The delivery of micro-interventions and their assessments as EMIs/EMAs is based on their characteristic to facilitate momentary delivery and proximal affect evaluation. During each time interval, with a probability of 50%, participants were randomised to receive an EMI, a probability choice based on prior research by Klasnja et al. (2015) and designed to minimise participant burden to participate while ensuring a balanced distribution of unobserved factors for accurate causal inferences (Klasnja et al., 2015; Rabbi et al., 2018; Walton et al., 2020). The randomisation ensured each participant had a unique schedule yet similar intervals, allowing for varied time-based effects analysis of micro-interventions (Walton et al., 2018). Momentary affect states were measured by EMAs administered immediately before and 30

minutes after receiving EMIs (Walton et al., 2018). This approach facilitated comparisons of affective states across intervals with and without micro-interventions, aiding in drawing reliable causal conclusions. Figure 3 visualises an example day: in every interval, there is a prompt point when the participant either randomly receives an EMA and EMI as in the first two intervals, measuring the momentary affect before an intervention or just an EMA, measuring just the momentary affect. The post-assessment through a second EMA is constant in every interval. Before and after the 15 days of intervention, participants' mental health was assessed via the baseline questionnaire (Base-Q) and post questionnaire (Post-Q) via Qualtrics.

Figure 3

Overview of an example study day



Data Collection & Analysis

The collected data was analysed with the statistics software R-studio. Participants were excluded from the analysis of distal outcomes if they had not completed the baseline questionnaires. Additionally, participants were excluded from the analysis of the m-path results if they had five or fewer interactions since this would indicate that the participants either quit the participation or did not participate regularly.

Because data gathered through MRTs is compiled using a longitudinal design, it is distinguished by its repeated measures for each individual. Fixed effect models fail to analyse

the nested structure that results from repeated measures designs, not considering random (time-varying) effects (Bell et al., 2019). Random effects consider the variability within groups with nested structures, whereas fixed effects show the average impact across all groups in the data. A statistical model that combines both fixed effects and random effects is a Linear Mixed Model (LMM) (Meteyard & Davies, 2020).

Two separate LMMs were conducted with *PA* and *NA* as dependent variables. Due to the repeated measures design of the MRTs, the collected data is nested in participants; therefore, the participant *ID* is included as a random effect in the models. An additional variable, "*Trial",* represents the micro trials nested within participants. Random effects were thus specified as observations nested within participants and trials. Two coefficients were added to this model as fixed effects: *condition (0 = PPI absent; 1 = PPI present)* and the interaction of *condition* and *time (1 = pre-assessment, 2 = post-assessment)*. The binary variable "*condition"* was chosen since it examines the primary impact of the presence or absence of a PPI and, therefore, measures its main effect on the dependent variable. The binary variable *time* indicates whether a data row represents a pre- or post-assessment. The interaction of both means a complete MRT in which the effect of the PPI depends on the impact of a pre-or post-assessment and vice versa. A significant effect of the interaction of *condition* and *time* would suggest that the PPIs as micro-interventions effectively improved the momentary PA or NA. Before running the LMM, several assumptions, including normality of residuals and homoscedasticity, were checked by applying plotted histograms and scatterplots.

To measure distal effects and answer the second research question, the mean scores of both time points of the baseline questionnaire, including the MHC-SF, PHQ-9 and the GAD-7 before and after the 15-day study, were compared using either a paired t-test or the Wilcoxon Signed Rank test. Effect sizes were measured with Cohen's D, which determines

the size of interventions' impact on the tests' results by quantifying the difference between the baseline questionnaire and post-questionnaire mean scores (Gignac & Szodorai, 2016). In the domain of PPIs, following Chakhssi et al. (2018), effect sizes (*d*) are interpreted as small (0 to 0.32), moderate (0.33 to 0.55) or large (0.56 to 1.2). Before applying the paired t-test, all items were checked for normality using the Shapiro-Wilk test, which indicates deviations from normality by a significant p-value.

To summarise the study's acceptance and feasibility, mean scores of rated items and several descriptive statistics were calculated and applied using data from the acceptance questionnaire.

Results

Overall, 47 people signed in to m-path, and the data of 12 participants was eliminated since it indicated less than five interactions with the app. Therefore, 35 people participated in the study by answering the m-path EMAs and participating in the EMIs. Of this sample, 28 answered the baseline questionnaire in Qualtrics. This sample's age ranged from 19 to 62, with an average of 25.93 years. Participants were predominantly female (82 %), of Dutch (35 %) and German nationality (50 %), students (75 %), and mainly high school graduates (79 %). Table 2 describes all demographics in detail. Overall, participants could answer at 2100 decision points during the 15 days. This sample answered a total of 975 trials (decision points), with one trial consisting of a pre and post-assessment through EMAs, leading to a response rate of 46.4 %. In 420 of the 975 trials, participants completed an EMI.

Table 2

Overview of demographics

Criteria	Category	n	%
		28	
Nationality	Dutch	10	35.71
	German	14	50.00
	Other	4	14.29
Gender	Female	23	82.14
	Male	5	17.86
Occupation	Student	21	75.00
	Working (Employed)	3	10.71
	Student & Working	2	7.14
	Other	2	7.14
Educational Level	Middle School	3	10.71
	High School	22	78.57
	Bachelor	1	3.57
	Master/ Diplom	1	3.57
	Other	1	3.57
Currently patient/client in a therapy program	Yes	4	14.29
	No	24	85.71

Proximal Outcomes

Table 3 overviews the first LMM results of both, the main effect condition and the interaction effect of *condition* and *time* on PA. The main effect of the presence of a micro-intervention on PA was not significant ($p > .05$). However, the effect of the interaction between condition and time and the dependent variable PA was statistically significant, $B = 0.14$, $p = .02$, 95% *CI* [0.02; 0.26], indicating that participation in a micro-intervention positively affects the participant's momentary PA. Likewise, the main effect of the presence of a micro-intervention on NA was not significant ($p > .05$), but the association between the

interaction of condition and time and the second dependent variable NA was statistically significant, B = -0.13, p = .03, 95% *CI* [-0.24; -0.02], indicating that the participation in a micro-intervention tends to reduce NA. Table 4 overviews the second LMM results of the non-significant main effect of *condition* and the significant interaction effect of *condition* and *time* on NA.

Table 3

Results LMM 1: Positive Affect (PA)

Effect	B	SE	t (df)	p	95% CI
condition	0.007	0.044	0.147 (1188)	.883	-0.08; 0.09
condition*time (interaction)	0.144	0.061	2.373 (1531)	.018	0.02; 0.26

Table 4

Results LMM 2: Negative Affect (NA)

Effect	B	SE	t (df)	p	95% CI
condition	0.055	0.042	1.302 (1193)	.193	-0.03; 0.14
condition*time (interaction)	-0.126	0.057	-2.214 (1547)	.027	-0.24; -0.02

Distal Outcomes

The Shapiro-Wilk test indicated that there were no deviations from normality for the MHC-SF (W_{pre} = 0.95, p_{pre} = .21; W_{post} = 0.93, p_{post} = .06) but that the post-assessment of the GAD-7 (W = 0.82, p < .01) and the PHQ-9 (W = 0.93, p = .04) significantly deviated from normality. Accordingly, a paired-samples t-test was applied for the MHC-SF, indicating a significant difference in scores from the MHC-SF's pre-assessment to MHC SF's post-assessment (p = .02). The well-being score increased on average by around 3.21 points suggesting a moderate effect size with d = 0.47 (Table 5).

Table 5

Outcome paired-samples t-test of the MHC-SF's pre- and post-assessment

Object	N	M	SD	d	df	t	p	95% CI
MHC-SF	28	43.04	12.18					
MHC-SF	28	46.25	12.77					
Paired t-test				0.47	27	2.5091	.018	0.586; 5.843

The Wilcoxon-Signed Rank Test found a significant difference between the mean scores of the GAD-7 pre-assessment and post-assessment ($V = 228$, $p = .03$), indicating a significant decrease in mean scores. The GAD-7 score decreased on average by 1.75 points, suggesting a small effect size ($d = 0.12$) (Table 6). Likewise, the Wilcoxon-Signed Rank test showed a significant difference between the mean scores of the PHQ-9 pre-assessment and post-assessment ($V = 285.5$, $p < .01$), indicating a significant decrease in mean scores. The PHQ-9 score decreased on average by 2.11 points, suggesting a moderate effect size ($d = 0.41$) (Table 7). All tests showed significant differences in mean scores but small to moderate effect sizes.

Table 6

Outcome Wilcoxon-Signed Rank test of GAD-7's pre- and post-assessment

Object	n	mean	SD	median	IQR	V	p	d
GAD-7 (pre)	28	8.71	5.37	8	7			
GAD-7 (post)	28	6.96	5.49	5	5.25			
Wilcoxon Signed-Rank test	28					228	.026	0.12

Table 7

Outcome Wilcoxon-Signed Rank test of PHQ-9's pre- and post-assessment

Object	n	mean	SD	median	IQR	V	p	d
PHQ-9 (pre)	28	9.07	5.11	7.5	5.5			
PHQ-9 (post)	28	6.96	4.62	6.5	5.25			
Wilcoxon Signed-Rank test	28					285.5	<.001	0.41

Acceptance Questionnaire Outcomes

The acceptance questionnaire revealed that participants felt moderately motivated to participate in the EMAs (M = 2.29, SD = 0.84) and the micro-interventions (M = 2.06, SD = 0.75) and rated the micro-interventions' helpfulness and usefulness slightly positive ($M_{helpfulness}$ = 6.26, $SD_{helpfulness}$ = 1.74; $M_{usefulness}$ = 6.14, $SD_{usefulness}$ = 2.06). The results showed that 54.29 % of all participants voted the micro-intervention "Three good things" as particularly helpful (Figure 5), followed by "Positive Memory" and "Express gratitude" (45.71 %). Additionally, 37.14 % of participants considered the "Personal strengths" micro-intervention particularly challenging (Figure 5). On the other hand, 28.57% of all participants voted for all micro-interventions as "not challenging". Overall, 19 out of 35 (54.30 %) participants experienced at least slightly positive changes through the micro-interventions, with five participants reporting significant positive changes and six reported any positive changes (Figure 6).

Figure 5

Votes (max. of 35 per category) for the questions which micro-interventions were helpful/ challenging

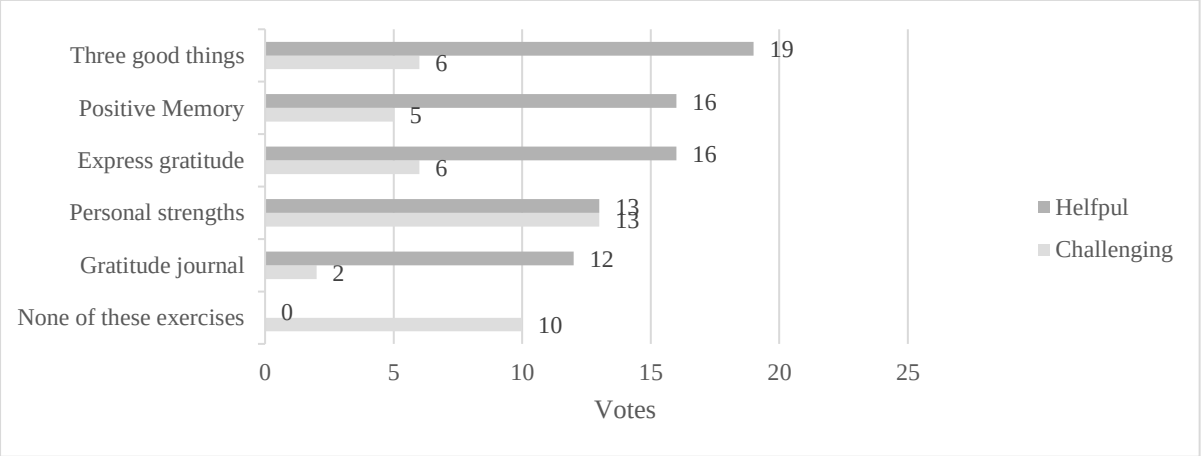


Figure 6

Scores (max. of 35 per category) of the question: Did you experience any positive changes in your mindset or well-being as a result of participating in this study?

Participants rated the difficulty of downloading (M = 0.86, SD = 0.94) and working with the app (M = 1.80, SD = 1.98) as low. Furthermore, understanding instructions for the micro-interventions was rated low (M = 1.98, SD = 1.46). All items assessing the overall clarity of the instructions of micro-interventions were rated with a mean score above 3 (>= "very much"), indicating the participant's clarity in instructions and micro-interventions.

The perceived participation burden was rated on five items, revealing a moderate burden for the EMAs (M = 2.17, SD = 0.89) and micro-interventions (M = 2.11, SD = 0.87). The integration of the study contents into the daily schedules was rated as moderately (>= 2) burdensome (M = 2.83, SD = 1.01), and the manageability of the number of EMAs and micro-interventions was rated as "very much" burdensome (M = 3.06, SD = 0.97). Additionally, participants reported they would have participated more if daily responsibilities hadn't been hindered (M = 3.49, SD = 1.12).

Discussion

The primary aim of this study was to investigate PPIs proximal effects on PA and NA and the 15-day interventions' distal effects on the overall mental health. A secondary objective was to evaluate the acceptance and feasibility of the innovative study method of MRTs for assessing PPI's proximal effects.

Effect on Proximal Outcomes

This study hypothesised that PPIs enhance PA and reduce NA close to participation derived from scientific sources promoting the role of PPIs in eliciting positive emotions and enhancing positive well-being (Sin & Lyubomirsky, 2009). Consistent with this hypothesis, the results demonstrated that PPIs, as micro-interventions, significantly increase PA and reduce NA immediately after participating in the micro-intervention. Therefore, the first research question regarding the proximal effects of PPIs as EMIs is answered affirmatively, with PPIs enhancing PA and reducing NA. These findings align with previous research which advocated that the selected PPIs (Table 1) were effective in eliciting positive emotions (Emmons & McCullough, 2003; Klibert et al., 2022; Lai, 2017; Layous et al., 2017; Niemiec, 2013; Schutte & Malouff, 2019). Notably, while prior research predominantly emphasised PPIs' effectiveness in augmenting positive emotions, this study has also unveiled their potential to mitigate negative emotions. Despite a slightly more substantial effect on PA, the

statistically significant impact on NA confirmed the potential of PPIs as micro-interventions to diminish negative emotions. Studies by Emmons & McCullough (2003) and Otsuka et al. (2012) claim that, for example, gratitude interventions not only impact PA but also reduce NA. Klibert et al. (2022) state that savouring exercises also trigger NA by inducing negative memories. Considering the findings of this current research and recent investigations of individual PPIs promotes the importance of NA in the context of PPIs. Thus, next to addressing positive emotions, warranting further investigation in future research dedicated to examining individual PPIs' effects on NA could improve negative emotional states.

As Klasnja et al. (2015) proposed, MRTs have been shown to help inform and optimise Just-in-Time Adaptive Interventions (JITAIs), which are personalised and dynamically delivered interventions providing timely support based on real-time assessments. This study underlines the immediate positive effects of PPIs delivered in micro-doses at different times daily. Since participants were assessed in various contextual settings, such as varying locations and times, PPIs as micro-interventions can enhance positive and reduce negative emotions in varying contexts. Therefore, micro-interventions could work effectively within JITAIs, which aim to administer personalised interventions at the right time (Nahum-Shani et al., 2018). Moreover, the findings align with the concept of easily accessible and practical mental health support through smartphone-based momentary interventions (Bidargaddi et al., 2020; Walton et al., 2018). As a key implication, the use of PPIs in micro-doses delivered through mobile apps provides an easily accessible opportunity for immediate mood improvements, which, incorporated in JITAIs, has the potential to complement traditional therapy. Future research should focus on the timely delivery of these micro-interventions to administer them when they are most helpful for an individual. Furthermore, the findings offer new avenues for mobile apps to deliver evidence-based, real-time support.

Effect on Distal Outcomes

Additionally, this present study hypothesised that PPIs positively influence increasing well-being and mental health in the long term (Bolier et al., 2013; Chakhssi et al., 2018; Hendriks et al., 2020). Participants reported significant increases in overall well-being and reductions in symptoms of anxiety and depression after engaging in the 15-day intervention. The results align with the findings of Bolier et al. (2013), Chakhssi et al. (2018) and Hendriks et al. (2020), which reviewed several PPIs and found small to moderate effect sizes for increasing well-being and alleviating symptoms of depression and anxiety. This study revealed that the MHC-SF's overall well-being score indicated a minor, statistically significant increase but also showed a small effect size, lowering the substantial magnitude of this increase. Similarly, the results of the GAD-7 and the PHQ-9 indicated significant changes in mean scores of the anxiety and depression scores but provided small and moderate effect sizes in both tests. A possible explanation underlying these observed minor changes could be the potential influence of a ceiling effect. The small increases/decreases in scores, though statistically significant, may have been constrained by the upper limit of the measurement scale (Wang et al., 2008). Given that the sample primarily consisted of participants currently not enrolled in any therapy program, it could have limited the scope for more extensive improvements in mental health outcomes. Additionally, the baseline questionnaire results revealed that participants, on average, had positive well-being and low anxiety and depressive symptoms starting this intervention. The minor yet significant positive changes after the intervention period underline the potential of PPIs in improving mental health states for individuals already reporting positive mental health.

In contrast to the proximal results that assumed causal effects of PPIs on momentary affect outcomes, drawing causal inferences for the distal outcomes is limited. It is not unambiguous that the continuous participation in PPIs alone was responsible for the measured changes over the intervention period. Therefore, an RCT could have advantages for

measuring distal effects since the design allows the comparison with a control group, limiting confounding factors (Bondemark & Ruf, 2015). However, since this study's results are consistent with previous literature, it is carefully assumed that PPIs work effectively in enhancing mental health. Considering this sample's results, indicating minor yet significant changes, the second research question can be answered affirmatively, concluding that PPIs positively impact the distal outcomes by improving well-being and reducing anxiety and depression symptoms over the 15-day intervention period. The positive changes in well-being, anxiety, and depression scores highlight the potential of mHealth interventions to contribute to the overall improvement of individuals' mental health. These findings align with the growing demand for accessible and practical mental health support, especially in light of the increasing prevalence of mental health issues worldwide (Bidargaddi et al., 2020). In the scope of prevalent mental health issues, future research needs to evaluate distal but also proximal findings regarding samples that are currently struggling with the presence of health problems since this would determine if the outcomes of this study do not solely apply to healthy samples. Especially PPIs falling under the category of savouring could induce negative memories, which could lower momentary as well as long-term well-being instead of promoting positive outcomes (Klibert et al., 2022).

Acceptance & Feasibility

The MRT approach provided a clear picture of proximal outcomes, successfully measured with EMAs, promoting the feasibility of micro-randomising PPIs to assess their causal effects. A crucial aspect was the delivery of micro-interventions and their assessments via smartphone. Prior research by de Vries et al. (2021) suggests the delivery of EMIs and EMAs via mobile devices since this facilitates an easy delivery and examination of micro-interventions and their effects. The acceptance questionnaire underlines the usage of smartphone-based approaches since it demonstrates that participants positively experienced

working with the app. Aligning with an RCT study by Howells et al. (2016), delivering interventions via smartphone shows high potential in enhancing mental health outcomes, which also aligns with more than half of the participants reporting at least "slightly positive changes" after the intervention. Although participants considered the exercises helpful and moderately burdensome, they experienced difficulties integrating several assessments into daily activities. The MRT requires a high burden through frequent assessments (Klasnja et al., 2015). Engaging in several assessments at various times a day demonstrated high effort and compliance for participants, indicating a significant disadvantage of the MRT (Walton et al., 2018). Future MRTs should consider reducing the burden to a minimum so as not to overburden participants to yield compliance, which is necessary to ensure consistent participation (Klasnja et al., 2015). The *Personal Strengths* micro-intervention was rated most challenging, which can be traced back to its required effort compared to the other micro-interventions. Therefore, as part of a micro-randomised trial, this task may overburden participants and is not feasible within this study design. On the other hand, participants reported that exercises such as *Three Good Things* were especially helpful. However, most importantly, no participants answered that none of the exercises was helpful, underscoring the helpfulness of used PPIs. This implies that future MRTs should stick to compact micro-interventions with short duration and easy integration into daily activities. By performing pilot studies, design choices such as the duration and feasibility of selected micro-interventions assure valid designs to analyse proximal effects. In the light of providing MRTs via mobile apps, the study contents were accepted and accessible for participants, promoting a cost-effective way of studying the effects.

Limitations & Strengths

This study presents several limitations and strengths. Primarily, using a small and homogeneous sample predominantly compromising young female individuals from Germany

or the Netherlands limits the generalisability of findings. This sample characteristic, a result of convenience sampling, poses a risk of biased outcomes due to its lack of diversity and representativeness of a broader population (Lopez & Whitehead, 2013).

Furthermore, the study's focus on a limited selection of PPIs may not fully capture their range, diversity, and adaptability to micro-interventions. Translating specific exercises like "Personal Strengths" into micro-interventions may not be suited for measuring proximal effects since they require participation that extends the frame of a micro-intervention regarding time and effort. Additionally, with each intervention applied for only three days, the study's duration could have constrained the depth of engagement and the potential long-term effects of these interventions.

Another fundamental limitation is the reliance on self-report measures, which, despite using EMAs to minimise recall bias, are vulnerable to social desirability bias and inaccurate self-assessment (Shiffman et al., 2008). The reliance might have led to responses reflecting expectations rather than actual experiences.

Despite these limitations, the study design utilising MRTs successfully measured proximal outcomes and enhanced the understanding of PPIs' causal effects on NA and PA. Randomising EMIs and EMAs at each delivery time point allowed it to collect momentary data on participants' affective states in their natural environment (Bhide et al., 2018), thus enhancing ecological validity (de Vries et al., 2021). Furthermore, using a smartphone-based intervention offered several benefits, including accessible and timely assessments and reminders, supporting efficient data collection and showing potential to provide mental health support beyond the therapy room.

Conclusion

In conclusion, this thesis provided evidence that PPIs delivered as EMIs positively impact immediate and long-term mental health outcomes. The outcomes are tempered by its

limitations, regarding a small and homogenous sample and a limited number of selected PPIs, which affect the generalisability of results. However, the innovative use of MRTs provided a deeper understanding of PPIs' proximal effects in a natural setting, with the advantage of drawing inferences on causal relationships between PPIs and their outcomes. The study uncovers possibilities for further exploration into PPIs in mHealth, particularly how they can be optimised as part of JITAIs to be timed and administered for maximum benefit.

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Appendix

Appendix 1

Mental Health Continuum – Short Form

Item	
	During the past month, how often did you feel …
1	happy
2	interested in life
3	satisfied with life
4	that you had something important to contribute to society
5	that you belonged to a community (like a social group, or your neighborhood)
6	that our society is a good place, or is becoming a better place, for all people
7	that people are basically good
8	that the way our society works makes sense to you
9	that you liked most parts of your personality
10	good at managing the responsibilities of your daily life
11	that you had warm and trusting relationships with others
12	that you had experiences that challenged you to grow and become a better person
13	confident to think or express your own ideas and opinions
14	that your life has a sense of direction or meaning to it

Appendix 2

Patient Health Questionnaire – 9

Item	
	Over the last 2 weeks, how often have you been bothered by any of the following problems?
1	Little interest or pleasure in doing things
2	Feeling down, depressed, or hopeless
3	Trouble falling or staying asleep, or sleeping too much
4	Feeling tired or having little energy
5	Poor appetite or overeating
6	Feeling bad about yourself or that you are a failure or have let yourself or your family down
7	Trouble concentrating on things, such as reading the newspaper or watching television
8	Moving or speaking so slowly that other people could have noticed. Or the opposite being so figety or restless that you have been moving around a lot more than usual
9	Thoughts that you would be better off dead, or of hurting yourself

Appendix 3

General Anxiety Disorder – 7

Item	
	Over the last two weeks, how often have you been bothered by the following problems?
1	Feeling nervous, anxious, or on edge
2	Not being able to stop or control worrying
3	Worrying too much about different things
4	Trouble relaxing
5	Being so restless that it is hard to sit still
6	Becoming easily annoyed or irritable
7	Feeling afraid, as if something awful

Appendix 4

Acceptance Questionnaire

Item	
1	Did you feel motivated to actively participate in the study exercises?
2	Did you feel motivated to actively participate in the study questionnaires?
	Rate on a scale from 1 (Not at all) to 10 (Very much)...
3	How useful did you find the exercises you were asked to complete during the study?
4	How helpful did you find the exercises you were asked to complete during the study?
5	What exercises did you find particularly helpful or useful?
6	Were there any exercises that you found particularly challenging?
7	Did you experience any positive changes in your mindset or well-being as a result of participating in this study?
	Rate on a scale from 1 (very easy) to 10 (very difficult)....
8	How difficult it was to download the app.
9	How difficult it was to work with the app.
10	How difficult it was to understand the instructions for the exercises.
	Please, answer some question about the studies' clarity.
11	I found the instructions for the daily exercises clear.

12	I knew what I would have to do for the daily exercises.
13	I found the daily questionnaires clear.
14	I knew how I would need to answer the daily questionnaires.
	Please, answer some question about your perceived burden during this study.
15	I found it burdensome to answer the questionnaires for this study.
16	I found it burdensome to complete the exercises for this study.
17	It was easy for me to integrate the questionnaires and exercises into my daily routine.
18	I found the number of exercises and questionnaires manageable.
19	I would have answered more questionnaires or completed more exercises, but was not able to because of my daily responsibilities hindered me to do so.

Appendix 5

Daily Questionnaire – Positive and Negative Affect Items

Item	
1	How cheerful do you feel right now?
2	How enthusiastic do you feel right now?
3	How satisfied do you feel right now?
4	How relaxed do you feel right now?
5	How anxious do you feel right now?
6	How irritable do you feel right now?
7	How down do you feel right now?
8	How sad do you feel right now?