Evaluating a Digital Micro-Intervention for Real-Time Emotion Regulation: A Within-Person EMA Study

Abstract

Emotion regulation difficulties are recognised as a transdiagnostic mechanism for psychological distress, yet traditional research often relies on retrospective methods that fail to capture regulation within the temporal dynamics of everyday life. The present study evaluated the feasibility and preliminary within-person behavioural impact of CalmStack, a threshold-triggered ecological momentary assessment (EMA)-based digital micro-intervention. Using a 14-day within-person baseline case series design (N = 11), participants completed a 4-day baseline phase followed by a 10-day intervention phase. Automated micro-interventions incorporating labelling, paced breathing, and cognitive reframing were triggered when momentary distress reached a specified threshold ≥6/10 across 941 observations, descriptive analysis indicated sustained engagement, with participants in the strict analytical sample completing an average of 117 intervention events. Post-intervention distress was lower across 76.9% of intervention phase observations, with a mean reduction of 2.88 points. Helpfulness ratings were consistently positive (M = 6.90), indicating that the low-burden format is acceptable and usable in naturalistic settings. While the absence of randomisation precludes causal inference, the findings provide a credible behavioural signal that real-time, context-sensitive support can meaningfully attenuate momentary distress. This study establishes a foundation for the development of fully adaptive, just-in-time systems capable of supporting emotion regulation in everyday life and work contexts.

1. Introduction

1.1 The problem: Emotion Regulation in Everyday Life

Emotion regulation refers to the process through which individuals influence the experience and expression of their emotions (Gross, 1998). It is central to adaptive functioning, enabling individuals to respond flexibly to environmental demands,

maintain goal-directed behaviour and recover from stress. When regulation fails, emotional responses may become prolonged, intense, and behaviourally disruptive.

Difficulties in emotion regulation are robustly associated with increased psychological distress, impaired functioning, and vulnerability across the wide range of mental health conditions (Gratz & Roemer., 2004) (Neacsiu et al., 2014). However, contemporary research increasingly conceptualises emotion dysregulation as a transdiagnostic mechanism, operating across both clinical and non-clinical populations (Sloan et al., 2017). This shift reflects a broader movement within psychological science towards identifying core processes that cut across diagnostic categories.

Recent population-level data further highlights the scale and relevance of these challenges in contemporary society. In the UK, personal well-being declined in the year ending March 2023, with 23.4% of people reporting high anxiety, up from 22.5% the previous year and levels of poor well-being remaining above pre-pandemic estimates (Office for National Statistics, 2023). Alongside this, national stress data suggests that emotional strain is embedded within everyday life rather than confined to clinical populations. For example, 74% of UK adults reported feeling so stressed at some point over the previous year that they felt overwhelmed or unable to cope. (Mental Health Foundation, 2018). Taken together, these findings suggest that difficulties in managing emotional responses are closely tied to contemporary pressures. Including work demands, financial strain and reduced opportunities for recovery in daily life.

Emotional distress often emerges in unpredictable high-pressure situations, including demanding work environments, interpersonal conflict, and periods of reduced support or fatigue. These moments are rarely structured or anticipated and often occur at times when cognitive resources are limited, such as during late night rumination, acute stress episodes, or periods of emotional overwhelm, individuals may struggle not only with emotional intensity but with implementing regulation strategies at the point they are most needed. This highlights a critical challenge for emotion regulation research and intervention. Supporting individuals in real time within the contexts in which emotional difficulties naturally arise.

As such, the central question is no longer simply whether individuals can regulate emotions, but whether they can do so effectively and at the appropriate moment. Gross's (1998) Process Model provides a temporal framework for understanding this challenge. Conceptualising emotion regulation as unfolding across multiple stages: Situation selection, situation modification, attentional deployment, cognitive change, and response modulation. A key distinction is drawn between antecedent-focused strategies, implemented early in the emotional trajectory and response focused strategies applied after emotional activation has intensified.

Empirical evidence consistently demonstrates that antecedent focused strategies such as cognitive reappraisal are associated with more adaptive outcomes, whereas response-focused strategies such as suppression, are linked to increased physiological strain and poorer psychological functioning (Gross, 2015) (Webb et al., 2012). This highlights a critical insight. The timing of regulation is as important as the strategy itself.

Despite this, much of the empirical literature relies on retrospective self-report or laboratory-based paradigms limiting the ability to capture emotion regulation as it unfolds in naturalistic settings. This creates a disconnect between theory and the measurement of emotion regulation in real-world contexts, where temporal dynamics are emphasised but often not captured by existing methodological approaches which often fail to measure them.

1.2 Purpose and Rational: From Theory to Momentary Support

Traditional emotion regulation research has relied heavily on retrospective self-report methods requiring individuals to recall emotional experiences hours or days after they occur. Memory is inherently reconstructive and subject to bias. Particularly under conditions of emotional arousal (Shiffman et al., 2008). Retrospective measures fail to capture the temporal dynamics of emotional experience.

Ecological Momentary Assessment (EMA) addresses this limitation by capturing experiences in real time and within natural environments, thereby reducing recall bias and increasing ecological validity. (Shiffman et al., 2008; Trull & Edner-Priemer 2020).

EMA can also function as a decision point within adaptive intervention systems. Just-in-Time Adaptive Interventions (JITAIs) extend this logic by using real-time data to determine when support should be delivered. (Nahum-Shani et al., 2017). Within this framework, timing is not incidental but represents the core mechanism through which intervention effectiveness is achieved.

Successful emotion regulation depends not only on strategy knowledge, but on the ability to deploy strategies under cognitive load. Executive functions, including attention, inhibition and perspective memory play a critical role in this process and failures in regulation often reflect failures in initiation rather than capability. (Hofmann et al., 2012), (Braunstein et al., 2017).

Digital interventions that integrate EMA with adaptive delivery mechanisms offer a potential solution to this problem. By detecting moments of heightened distress and delivering support in real time, such systems reduce reliance on self-initiated strategy deployment under cognitive load and align intervention delivery with the temporal dynamics of emotional experience.

Despite strong theoretical alignment, there remains limited empirical evidence from designs that directly examined immediate within-person regulatory change in naturalistic settings.

1.3 Literature review

1.3.1 Emotional Regulation and Distress in Daily Life

Emotional regulation research has consistently demonstrated that the effectiveness of regulatory strategies depended on both strategy type and timing. While Gross's (1998) Process Model provides the theoretical foundation, subsequent research has refined understanding on how specific strategies function in applied contexts.

Meta-analytic evidence indicates that cognitive reappraisal is associated with reduced negative affect and improved psychological outcomes, whereas expressive suppression is linked to increased physiological activation and poorer wellbeing (Webb et at., 2012). These findings reinforce the importance of intervening early in the emotional trajectory.

However, a key limitation of this literature is its reliance on retrospective or laboratory-based designs. While these approaches provide controlled insight into regulatory processes, they offer limited ecological validity and fail to capture how regulation unfolds in everyday life.

Which obscured the temporal dynamics of emotion regulation and limited insight into how strategies are deployed at the moment of emotional activation. As a result, these approaches may underestimate the importance of timing and fail to capture the conditions under which regulation succeeds or breaks down.

Another key limitation of this literature is that while theoretical models emphasise the importance of timing in emotion regulation, they often assume that individuals are able to deploy strategies at the appropriate moment. In practice, periods of heightened distress are precisely when regulatory capacity is most impaired, creating a gap between the onset of emotional responses and the successful application of regulation strategies. This “timing gap” represents a critical limitation in translating theory into real-world effectiveness.

1.3.2 Measuring Emotional Regulation in Naturalistic Settings

Measurement is central to addressing this limitation. While retrospective self-reports remains widely used, it is poorly suited to capturing momentary emotional processes. (Shiffman et al., 2008).

The Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2004). Provides a well-established measure of trait-level regulation difficulties. It is a shorter version than the DERS-16, retains strong psychometric properties while reducing participant burden, making it suitable for applied and repeated-measures research. (Bjureberg et al., 2016). However, trait measures cannot capture rapid fluctuations in emotional state.

To address this, state-based adaptations of emotion regulation measures have been developed. These allow researchers to assess constructs such as emotional clarity and nonacceptance in real time (Lavelle et al., 2018). When embedded within EMA protocols, these measures provide a way to track within-person changes as they occur.

Combining trait-level assessment with momentary state measurement represents a robust approach to studying emotion regulation in naturalistic contexts. It allows researchers to examine both baseline vulnerability and immediate regulatory change.

Although combining trait-level assessment with momentary state measurement provides a more comprehensive framework, many studies still rely on between-person comparisons or aggregated data. As a result, the ability to capture rapid, within-person regulatory change remains limited, particularly in real-world contexts where emotional experiences fluctuate dynamically.

Ecological Momentary Assessment (EMA) offers a methodological response to these limitations by capturing the emotional states in real time and reducing recall bias. (Shiffman et al., 2008). However, while EMA improves measurement precision, it does not in itself provide regulatory support. This highlights the need to combine real time assessment with adaptive intervention frameworks, such as Just-in-Time Adaptive Interventions (JITAIs), which aimed to deliver support contingent on an individual's current state (Nahum-Shani et al., 2018). However, these approaches remain limited in capturing rapid within-person regulatory change in real-world contexts.

1.3.3 Digital Micro-Interventions and Just-in-Time Adaptive Logic

Just-in-Time Adaptive Interventions (JITAIs) provide a structural framework for delivering support based on real-time data (Nahum-Shani et al., 2018). These systems rely on clearly defined components: decision points, tailoring variables, decision rules, and intervention options.

Within this framework, digital micro interventions, digital micro interventions brief focused strategies delivered in under a minute are particularly suited to high-demand environments where cognitive resources are limited (Myin-Germeys & Kuppens, 2021). Their brevity reduces burden while maintaining relevance at the moment of need.

Evidence suggests that app-based emotion regulation interventions are both feasible and acceptable in daily life contexts (Fuller-Tyszkiewicz et al., 2018). However, many

digital tools prioritise engagement metrics over precise testing of psychological mechanisms.

To address this gap, the present study evaluated CalmStack, a researcher developed digital micro-intervention designed to provide brief in-the-moment support for emotion regulation. The system operationalises JITAI principles through a structured Red-Amber-Green model, using momentary distress thresholds to trigger targeted regulatory strategies derived from Dialectical Behaviour Therapy (DBT) and Acceptance and Commitment Therapy (ACT).

Recent research highlights that digital mental health interventions are most effective when they are context-sensitive, low-burden and temporally aligned with user needs (Myin-Germeys et al., 2021; Wang & Miller, 2020).

These developments highlight the importance of context-sensitive and accessible digital intervention designed within real-world contexts. This emphasis from low-burden, context-sensitive delivery also aligns with broader work on digital mental health design and ethics. In parallel, culturally grounded research highlights that stress, coping and engagement with support tools are shaped by lived experience, identity, and trust in systems of care (Byfield, 2019). More recent work further suggests that co-designed health technologies may be more accessible and acceptable for diverse user groups (Salunke et al., 2025). This reflects a broader limitation across the literature where real time measurement (e.g., EMA), adaptive intervention delivery, (e.g., JITAI) and within-person analytical approaches are rarely fully integrated within a single design. These real-world contexts highlight a central challenge whether individuals can regulate emotions effectively at the moment they are most needed.

The present study addresses this gap by evaluating CalmStack, a research-developed design micro-invention that operationalises JITAI principles through a structured Red-Amber-Green model. By combining EMA-based measurements, threshold-triggered intervention delivery, and within-person analysis, the study examines whether brief context-sensitive support can produce immediate reductions in distress as emotional experiences unfold in everyday life.

In studies that integrate real-time measurements (e.g., EMA), adaptive intervention delivery (e.g., JITAI), and within-person analytical approaches, addressing this gap is

essential for determining whether digital interventions can meaningfully influence emotion regulations as it unfolds in everyday life.

A key issue underlying this gap is not the absence of theoretical models, but a limitation in their temporal application. Gross's Process Model of Emotion Regulation (1998; 2015) outlines multiple points of intervention across the emotion-generative process, yet it implicitly assumes that individuals can deploy strategies at the appropriate moment. In contrast, research on emotion dysregulation, particularly as measured by the Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2004), highlights impairments in emotional clarity, impulse control, and strategy access during periods of heightened distress. Thus creates a critical "timing gap" between distress onset and strategy deployment.

Real-time digital interventions, particularly those embedded within EMA frameworks, offer a potential mechanism to bridge this gap by delivering support within the flow of everyday life rather than relying on retrospective reflection or pre-planned coping strategies, such approaches can scaffold in-the-moment awareness and action.

Within this context, the present study examines whether a brief EMA-triggered digital micro-intervention can support immediate within-person reductions in distress, thereby aligning regulatory support with the temporal dynamics of emotional experience. Emotion regulation failure in everyday contexts may therefore reflect not a lack of strategy knowledge but a failure of timely strategy deployment.

1.4 Research Aim and Research Questions

Research Aim

To examine whether a real-time EMA-triggered digital micro intervention (CalmStack) is associated with immediate within-person reduction in emotional distress following moments of elevated distress in naturalistic daily-life contexts.

Research Questions.

RQ1 Immediate Effects (Primary)

Is use of a CalmStack micro-intervention associated with immediate within-person reductions in momentary distress?

RQ2 State Regulation (Primary)

Is use of the intervention associated with immediate improvements in state-level emotional regulation (e.g., emotional clarity and perspective manageability)?

RQ3. Individual Differences. (Secondary/ Exploratory)

Does baseline emotional regulation difficulty (DERS-16) moderate levels of momentary distress and responsiveness to the intervention?

Method

2.1 Study Design

This study employed a 14-day within-person baseline case series design using

Ecological Momentary Assessment (EMA) all within a Just-in-Time Adaptive Intervention (JITAI) framework. This design enabled examination of moment-to-moment changes in emotional distress and state-level emotion regulation in naturalistic daily-life contexts, with each participant acting as their own comparator across phases. EMA is well suited to capturing proximal psychological processes due to its real-time sampling, reduced recall bias, and high ecological validity. (Shiffman et al., 2008; Trull & Ebner-Priemer, 2020).

The study comprised two sequential phases. During the baseline phase (Days 1-4), participants completed EMA check-ins without intervention. During the intervention phase (Days 5-14), the same EMA schedule continued, with a brief digital micro-intervention delivered when momentary distress met a pre-specified threshold. This structure enabled comparison between naturalistic emotional fluctuations and responses following intervention availability.

The design was pre-specified in the approved ethics application and implemented within the Gorilla platform. No randomisation or experimental manipulation was used, instead the design relied on repeated within-person observations to examine the immediate within-event change and patterns over time.

The primary predictor was delivery of the threshold-triggered CalmStack micro-intervention initiated when momentary distress reached ≥6 on a 0-10 scale. Primary

outcomes included momentary distress and state-level indicators of emotion regulation, particularly emotional clarity, and perceived manageability. Baseline DERS-16 scores were included to examine individual differences in trait emotion regulation and exploratory moderation be effects.

Taken together the design enabled direct examination of immediate within-person change, repeated measurement across time and exploratory between-person variation, a feasibility-focused naturalistic framework.

This approach necessarily involves trade-offs, including reduced control over extraneous variables and variability in participant engagement, which are integral to assessing real-world applicability. Full materials and extended documentation are provided in the appendices.

2.2 Participants

Approximately 20 adults aged 18 years and over residing in the United Kingdom were recruited via opportunity sampling through online channels.

Eligibility criteria included age (18+) and UK residency, which were confirmed through initial screening questions administered within the Gorilla platform as part of the onboarding process. Participants were also required to be able to complete EMA prompts independently using a personal digital device. Participation was voluntary and no financial compensation was provided.

Consistent with the studies, transdiagnostic focus participants were not excluded based on mental health diagnosis, medication use, or prior therapy. Exclusion criteria were restricted to situations involving elevated clinical risk, including acute psychological crisis, active suicidal intent, or engagement in intensive clinical care requiring coordinated support. Participants meeting exclusion criteria were not permitted to proceed past the onboarding process.

Across the 14-day protocol, each participant could contribute up to 56 EMA observations, generating a dense data set suitable for examining within-person variation a minimum sample of 10 participants was specified the priority as sufficient for preliminary estimation of within-person effects in a feasibility-focused design.

Descriptive statistics for participant characteristics and engagement are presented in Table 1.

Table 1. Participant characteristics and engagement metrics.

Variable	Value
Final tracked participants (N)	11
Participants with intervention data	9
Intervention events (total)	941
Intervention events (mean per participant)	105.0
Intervention events (SD)	40.2
Intervention events (range)	10–131

Demographic variables such as gender and age were not collected as they were not central to the study aims.

2.3 Measures

2.3.1 Trait Emotion Regulation

Trait-level emotion regulation difficulties were assessed using the Difficulties in Emotion Regulation Scale-16-item version (DERS-16; Bjureberg et al., 2016). The DERS-16 is a validated self-report instrument measuring difficulties across multiple domains of emotion regulation, including emotional clarity, nonacceptance of emotional responses, impulse control and difficulties engaging in goal-directed behaviour. It was selected because it provides a concise but psychometrically robust measure of trait-level dysregulation while reducing participant burden in repeated-measures research.

Participants completed the DERS-16 once at baseline on Day 0, prior to the commencement of EMA monitoring. The measure was used to capture trait-level emotion regulation difficulties at study entry Baseline DERS-16 scores were subsequently used in exploratory analysis to examine whether individual differences

in trait emotion regulation were associated with overall distress levels and responsiveness to the intervention.

Although the DERS-16 captures trait-level emotion regulation difficulties, the EMA and post-intervention items reflect momentary, state-level regulatory processes, allowing examination of how stable individual differences relate dynamic emotional experiences.

2.3.2 State Emotion regulation and distress (EMA)

Momentary emotional states were assessed using ecological momentary assessment delivered four times per day across the 14-day study. Each EMA prompt comprised a brief set of state-level items designed to capture current distress and key components of state emotion regulation in real time, consistent with the ethics-approved protocol.

All EMA items were rated on A 0-10 visual slider, where higher scores indicated greater endorsement of the construct. Momentary distress was assessed using the item, “How distressed do you feel right now?” with anchors ranging from 0 (not at all distressed) to 10 (extremely distressed). Emotional awareness was assessed using the item, “Right now I am aware of what I am feeling.” Emotional clarity was assessed using the item, “Right now, I understand I am aware of what I am feeling.” Emotional manageability was assessed using the item. “Right now, I feel able to manage my emotions.” Goal-directiveness was assessed using the item, “Right now I am able to stay focused on what I am doing.”

The 0-10 response format was selected to optimise usability while maintaining sensitivity to within-person fluctuations in emotional state. The use of a consistent scale across EMA ratings, intervention trigger thresholds and post-intervention responses supported coherence across the full protocol. Because these state-level EMA items were single-item indicators, internal consistency coefficients were not applicable. However, they functioned as face-valid measures of momentary emotional experience and state regulation within an intensive longitudinal design. This approach is consistent with intensive longitudinal methodology, in which single item measures are commonly used to minimise participant burden while maintaining sensitivity to within-person change (Fisher & To, 2012; Trull & Ebner-Priemer 2020).

A pre-specified threshold of ≥6 on the distress item was used to trigger the delivery of the micro intervention within the EMA sequence.

2.3.3 Micro-intervention engagement

When a threshold-triggered micro-intervention was delivered, participants completed a brief set of post-skill ratings intended to capture immediate engagement and perceived effectiveness. These items were presented immediately after completion of the intervention and before returning to the main EMA flow. The intervention itself consisted of a brief (15-30 seconds) structured sequence involving emotion labelling, paced breathing and a one-line cognitive reframe.

Participants rated post-intervention emotional clarity using the item. “Right now, I understand what I am feeling,” and post-intervention emotional manageability using the item, “Right now, I feel able to manage my emotions.” They also rated perceived helpfulness using the items, “How helpful with this exercise for you right now?” All post-intervention items were rated from the same 0-10 scale used throughout the EMA protocol.

These post-skill responses served as proximal outcome indicators, capturing immediate perceived changes in distress and emotion regulation following the CalmStack intervention. This approach is consistent with JITAI logic, in which short-term state-level shifts are assessed in close temporal proximity to intervention delivery.

2.4 Procedure

2.4.1 Onboarding (Day 0)

Participants access the study remotely via the Gorilla.sc platform using their own devices. Onboarding consisted of reading the Participant Information Sheet, providing electronic consent, completing eligibility, and safeguarding screening and completing the baseline DERS-16. This study was framed as a real-world low-burden investigation of emotion regulation in everyday settings including busy day-to-day, academic, and work-related context. Participants were informed that the study did

not constitute a therapeutic or crisis service, that responses were not monitored in real time and that they could withdraw at any stage prior to anonymisation.

2.4.2 Baseline Phase (Days 1-4)

During the baseline phase, participants completed one e-mail check in each morning at approximately 8:00 a.m. Each prompt required approximately 60 to 90 seconds to complete. No intervention content was delivered during this phase, irrespective of reported distress level unless ≥9 This would then trigger the support screen, pointing participants where to seek immediate help if needed. The purpose of the baseline phase was to establish each participant's naturalistic pattern of emotional fluctuation and state emotion regulation prior to the introduction of intervention support.

2.4.3 Intervention Phase (Days 5-14)

During the intervention phase, the same EMA schedule continued. At each check-in, participants first reported their current level of distress and other state-level indicators. When participants reported momentary distress at ≥6 or above on the 0-10 scale, a Just-in-Time adaptive intervention was triggered automatically. This delivery was fully automated within the Gorilla platform and did not involve real-time researcher input.

Two decision rules, governing intervention, and safeguarding delivery. First, distress ratings of ≥6 or above triggered a brief 15-30 second emotion regulation micro-intervention. Second, distress ratings of ≥9 or above triggered a micro-intervention but participants were also signposted to safeguarding screen directing participants to relevant external support resources due to platform constraints within Gorilla, this was implemented as a single instance trigger rather than a repeated-threshold rule.

The distress threshold of ≥6 was pre-specified as the activation point for intervention delivery, based on the need to capture moderate-to-high levels of momentary distress, while avoiding unnecessary interruption during low-intensity states. Immediately following the intervention, participants completed post-intervention ratings assessing emotional clarity, emotional manageability, and perceived helpfulness. This structure enabled direct within-event comparison between pre- and post-intervention responses while maintaining temporal proximity between

intervention delivery and outcome measurement consistent with JITAI design principles.

2.4.4 Reflection

Participants were also given the option to provide a brief written reflection during the EMA process. These reflections could be completed following check-ins and, where relevant, after engagement with the micro-intervention reflections were optional and were designed to capture contextual information about emotional experiences, perceived usefulness of the intervention and situational factors influencing distress. These data were collected for exploratory qualitative insight and were not included in the primary quantitative analysis. All reflections were anonymised and were not used to trigger interventions or safeguarding responses.

All procedures were conducted in accordance with the approved ethics protocol and implemented as specified within the Gorilla platform.

2.5 Ethical Considerations

Ethical approval was granted by the Nottingham Trent University School of Social Sciences Research Ethics Committee (S3REC) and was conducted in accordance with the British Psychological Society (BPS) Code of Human Research Ethics (2014).

Participants provided fully informed electronic consent prior to participation and were informed of their right to withdraw from the study at any time without penalty up to the point of anonymisation. Participant autonomy was further supported through the voluntary nature of all EMA responses and the optional nature of diary reflections.

Because this study involved repeated measurement of distress in real time, particular attention was given to safeguarding. Participant responses were not monitored live, reducing the risk of therapeutic misconception or inappropriate expectations of researcher intervention. Instead, automated safeguarding thresholds were embedded within the platform so that elevated distress levels triggered an automated signposting screen directing participants to external support services, including. NHS

and crisis resources. This approach supported participant safety while maintaining clear boundaries around the role of this study.

The intervention was explicitly framed as non-therapeutic. Participants were informed that CalmStack did not constitute diagnosis, treatment or personalised psychological support and no individual feedback was provided during data collection. This reduced the risk of role confusion and over reliance on the intervention as a substitute for formal care.

Data protection and proportionality were addressed through a low-burden data minimisation approach. All data were collected anonymously, stored securely in GDPR-compliance systems, and accessed only by the researcher. No passive sensing, location tracking or personally identifiable information was collected, ensuring that data collection remained proportionate to the aims of the study. In line with open research practises, anonymised datasets and analysis code may be made available upon reasonable request, subject to ethical and data protection considerations.

2.6 Analytic Approach

Data analysis was conducted in R, a statistical programming environment used for data management analysis and reproducible workflows. Descriptive statistics were calculated to summarise participant characteristics, engagement, and distress levels across this study.

Within-person changes in distress were examined by comparing pre- and post-intervention ratings for each intervention event. Mean change scores were calculated at both the event level and participant level. Additional descriptive summaries were produced for post-intervention distress, emotional clarity, perceived manageability, and perceived helpfulness rating.

Analysis focused on four main objectives. First, participant engagement and data completeness were examined by describing the number of participants contributing data across the study, including broad and strict analytical samples and by summarising the frequency of EMA responses and interventions events. Second, the distribution of distress levels was summarised using descriptive statistics. Third,

paired pre-post distress observations were used to examine the magnitude and direction of immediate change following intervention exposure, including the proportion of observations showing reduction, no change or increase in distress. Change scores were computed as the difference between post-intervention and pre-intervention distress ratings for each event. Fourth, perceived helpfulness ratings were summarised descriptively, and optional reflections were reviewed for contextual insight but not formally analysed.

The final integrated event-level dataset consisted of repeated within-person observations across time, with each intervention event containing paired pre- and post-intervention responses. This structure enabled examination of immediate within-event change and comparison between baseline (no-intervention) and intervention phases at the state-level. In addition, baseline DERS-16 scores were used in exploratory analysis to examine whether trait-level emotion regulation difficulties were associated with overall distress levels or responsiveness to the intervention.

Missing data were not imputed and were treated as expected within EMA designs, with all analysis conducted using available data only. Although the study was not powered for multilevel modelling the data structure is consistent with hierarchical (nested) analysis frameworks. While formal multilevel modelling (e.g., linear mixed-effects models) was not implemented due to sample size constraints, the analytical approach aligns with within-person designs commonly examined using hierarchical models in larger samples.

2.7 Open Research and Data Availability

Data for this study were collected via Gorilla and processed using R. Due to ethical and confidentiality constraints, including the collection of sensitive self-report data, the full dataset is not publicly available.

However, anonymised datasets, data dictionaries and processing documentation can be made available upon reasonable request to the author, subject to ethical approval and data protection considerations.

All data were managed and stored in accordance with Nottingham Trent University research ethics guidelines. A full record of data collection, processing and analysis procedures has been retained and verified by the project supervisor.

2.8 Feasibility Context and Implementation Notes

This study was conducted as a feasibility trial rather than a fully powered effectiveness study. The primary aim was to assess whether a brief digital micro-intervention could be delivered in naturalistic settings and whether participants would engage with repeated EMA check-ins across the study period. In line with feasibility objectives, the study focused on recruitment, adherence, usability, and preliminary behavioural signals rather than definitive causal inference.

Because the intervention was delivered in participants' everyday environment, variability in timing and engagement was expected. Participants did not always complete check-ins at fixed intervals, and some prompts were missed or affected by technical issues. These factors reflect the practical realities of delivering digital interventions outside controlled laboratory settings and are important for interpreting the findings, particularly in relation to feasibility and real-world applicability.

Results

This section reports the outcomes of the Ecological Momentary Assessment (EMA) protocol and the associated threshold-triggered micro-intervention. Results are presented sequentially, beginning with data preparation and analytical structure followed by participant engagement, distribution of distress, event-level changes in distress and perceived usefulness. In line with the feasibility-focused design, analyses are descriptive and pattern-based interpretation is reserved for the Discussion.

3.1 Data Preparation Analytical Approach

Data were exported from Gorilla as multiple event-level datasets, including onboarding responses, EMA check-ins, Difficulties in Emotion Regulation Scale

(DERS-16) responses and intervention logs. No single consistent participant identifier was present across all files. To address this, a structured crosswalk procedure was implemented to resolve inconsistencies in participant identifiers and re-establish continuity across data sets.

Participant identifiers were examined within the secure Gorilla environment to determine correspondences across datasets. A mapping system was then constructed enabling the creation of a unified participant key. Following this process, all subsequent data handling and analysis were conducted using anonymised datasets.

All datasets were standardised and integrated into a single event-level master dataset. This dataset was partitioned into analytical subsets including a full dataset, a broad sample comprising participants who engaged with the intervention and district sample comprising participants with elevated levels of response completeness.

Data cleaning procedures included removal of incomplete or invalid entries (e.g., missing timestamps or absent responses), validation of response ranges (0-10 for distress), and verification of pre-post distress pairings to ensure correct temporal sequencing. Missing data were not imputed and were managed using an available-case approach.

Given the feasibility-focused design and variability in response completeness, analysis was primarily descriptive, with a supplementary non-parametric test used to evaluate pre-post changes in distress.

3.2 Participant Engagement and Response Frequency

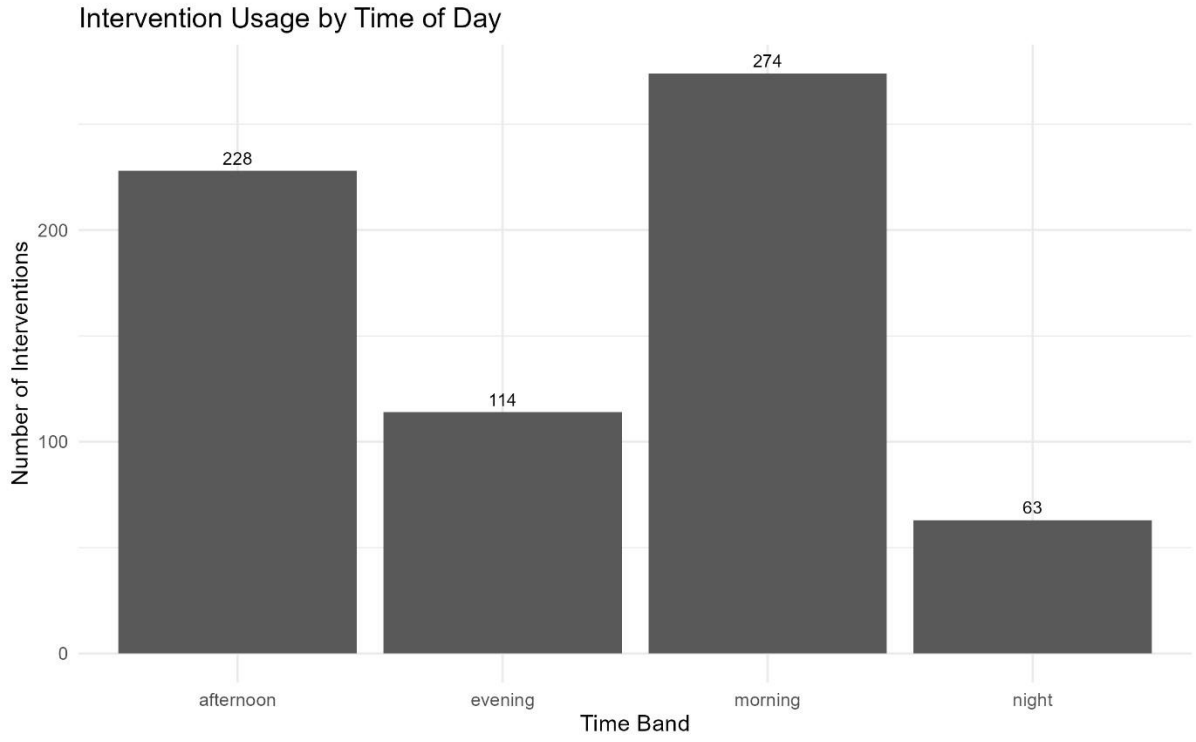
Participants demonstrated sustained engagement with both EMA Check-ins and intervention events across this study period.

Within the broad sample (n = 9), the mean number of intervention events per participant was 104.56 (SD = 40.16), with a range from 19 to 153 events. Within the strict sample (n = 5), The mean number of intervention events was 117.60 (SD = 31.43), with a range from 83 to 153 events.

Engagement with EMA check-ins was similarly consistent. Participants in the broad sample completed a mean of 74.44 responses, (SD = 10.00), while those in the strict sample completed a mean of 77.00 responses (SD = 9.00).

Engagement levels varied across participants but were sustained across the study.

Intervention usage varied across time of day, with the highest frequency observed in the morning, (n = 274), followed by afternoon (n = 228), evening (n = 114), and night (n = 63), As shown in Figure 1



3.3 Distribution of Reported Distress Levels

Across all recorded observations, (n = 941), The mean distress score was 4.79 (SD = 3.27), with values ranging from 0 to 10.

Within intervention-relevant subsets, the mean distress score was 4.86 for in-window observations and 4.95 during intervention phases. Distressed scores were distributed across the broad range of values.

3.4 Observed Changes in Distress Following Intervention Use

Analysis of paired distress observations (n = 625) showed a mean reduction in distress of 2.22 points (SD = 3.18).

A Wilcoxon signed-rank test indicated that post-intervention distress scores were significantly lower than pre-intervention scores (V = 122,741, p < .001).

Within constrained subsets, the mean reduction increased to 2.74 for in-window observations and 2.88 during intervention-phase observations.

Across all paired observation:

- 70.7% showed a reduction in distress.
- 14.7% showed no changes.
- 14.6 showed an increase.

Within intervention-phase observations 76.9% of cases showed reduced distress following intervention use.

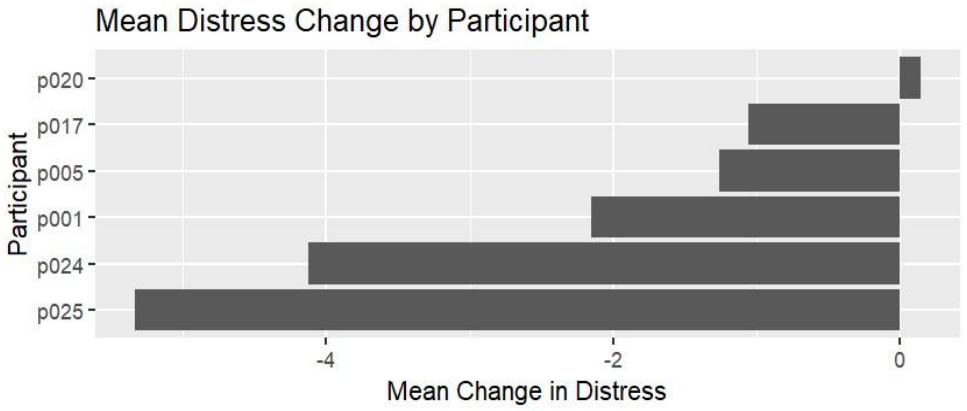
Reductions were observed across both full and constrained analytical subsets.

Summary. Statistics for distressed change across analytical subsets are presented in Table 2.

Pre-post distress changes across analytical subsets.

Subset	n	Mean Change	SD	% Reduced
All observations	625	-2.22	3.18	70.7%
In-window	515	-2.74	3.00	74.8%
Intervention phase	472	-2.88	3.02	76.9%

Table 2. Pre-post distress changes across analytical subsets.



Participant-level variability in distress change is presented in Figure 2.

3.5 Post-intervention Distress Levels

Post-intervention distress levels were generally lower than pre-intervention levels across most recorded events.

The mean post-intervention distressed score across all observations was 3.81, with a lower mean of 3.10 observed within intervention-phase.

3.6 Perceived Helpfulness of The Intervention

Helpfulness ratings were available for the subset of responses.

The mean helpfulness rating across all the data was 6.51 (SD = 2.26), increasing to 6.83 in-window observations, 6.90 during intervention phase. Rating ranged from 1-10. Helpfulness rating varied across intervention events.

3.7 Qualitative Feedback on Intervention Use

Participant reflections provided contextual insight into the quantitative findings. Responses varied across individuals and across time, reflecting differences in emotional state and perceived need.

Some participants described experiencing elevated distress and reported that the intervention supported emotion regulation. Other responses indicated low or absent distress (e.g., “I'm not stressed, I'm fine”), suggesting that prompts were sometimes encountered outside periods of acute need.

Reflections indicated that intervention engagement varied according to momentary context and perceived relevance, rather than occurring exclusively during high-distressed states.

4. Discussion

4.1 Overview of Findings

The present study examined the feasibility and preliminary behavioural outcomes of a digital micro-intervention delivered within an ecological momentary assessment (EMA) framework in naturalistic settings. The findings indicate that the system was practically implementable, that participants engaged consistently over time, and that self-reported distress was lower following intervention use across the majority of paired observations.

Engagement was sustained across both analytical samples, with participants in the broad sample completing an average of 104 for intervention events and those in the strict sample completing an average of 117 events. Approximately 90.9% of tracked participants engaged with the intervention, indicating strong behavioural uptake despite limitations in delivery infrastructure due to platform constraints within Gorilla, safeguarding thresholds were operationalised as single instance triggers rather than repeated thresholds.

At the event level, distress was reported across a wide range (mean = 4.79), with higher values observed within intervention relevant subsets. Paired observations demonstrated mean reductions in distress ranging from 2.22 points across all observations to 2.88 points within intervention-phase data. Furthermore, 76.9% of intervention-phase observations showed a reduction in distress and helpfulness ratings were consistently positive. Increasing from a mean of 6.51 overall to 6.90 during intervention phases.

The intervention was feasible to implement, acceptable to participants and associated with short-term reductions in self-reported distress. However, given the descriptive and exploratory nature of the design, these results should be interpreted as preliminary behavioural patterns rather than definitive evidence of efficacy.

The observed reductions in distress following intervention use may be understood through multiple, interacting regulatory mechanisms. First, the intervention likely facilitates attentional redirection, interrupting ongoing emotional escalation by shifting cognitive focus away from distressing stimuli. This aligns with attentional deployment strategies within Gross's Process Model and may be particularly relevant in high intensity emotional states where cognitive narrowing occurs, particularly in high-

stakes environments such as healthcare or corporate settings where attentional disruption can impair performance.

In addition, the intervention shares functional overlap with skills-based approaches derived from Dialectical Behaviour Therapy (DBT), particularly in its emphasis on distress tolerance and rapid, in-the-moment regulation. The structured sequence of labelling, breathing, and reframing reflects core DBT principles aimed at stabilising emotional intensity without requiring extended cognitive processing.

Furthermore, observed changes in clarity and manageability may be interpreted in relation to broader emotion regulation domains assessed by the DERS, while remaining conceptually distinct as state-level indicators of momentary regulatory experience. This suggests that the intervention may influence state-level manifestations of broader emotion regulation capacities.

Second, the structured nature of the intervention supports elements of cognitive reappraisal, enabling individuals to reframe their emotional experience in a more manageable or coherent manner. Even brief prompts to label or contextualise emotional states have been shown to enhance emotional clarity and reduce effective intensity.

Third, the inclusion of paced breathing components may engage physiological regulation process is particularly through modulation of autonomic activity. Slow, controlled breathing has been associated with increased parasympathetic activation and reductions in physiological arousal, suggesting that the intervention may operate not only at a cognitive level but also through embodied regulatory pathways. (Lehrer & Gevirtz, 2014)

Taken together, these findings suggest that the effectiveness of the CalmStack intervention may derive from its capacity to simultaneously target cognitive, attentional, and physiological aspects of emotion regulation within a rapid, accessible format.

4.2 Interpretation in Relation to Theory and Prior Research

The findings are broadly consistent with established models of emotion regulation, particularly those emphasising the importance of temporal proximity between emotional activation and regulatory intervention. Gross's Process Model suggests that earlier-stage interventions are generally more effective than those applied after emotional responses have fully developed. In this context, observed reductions in distress following intervention use are consistent with the proposition that brief, proximal support may attenuate escalating emotional responses. The combination of repeatedly EMA measurement and threshold-based intervention logic reflects this framework and consistent with Just-in-Time Adaptive Intervention (JITAI) principles, which emphasise the delivery of support at moments of heightened vulnerability. (Nahum-Shani et al., 2018).

However, a key limitation must be acknowledged. Although the intervention was designed in accordance with JITAI principles (Nahum-Shani et al., 2018). It. did not function as a fully adaptive real-time system. Delivery depending on participation-initiated engagement rather than passive sensing or continuous monitoring. As such, the system represents a threshold-triggered self-reported mediated. JITAI approximation rather than add fully adaptive model, which has implication for both timing precision and potential intervention impact.

Behavioural patterns further extend this interpretation. Participants engaged with the intervention across a range of emotional states, suggesting that the system may function not only as a reactive regulation tool but also as a mechanism for ongoing self-monitoring, consistent with evidence that repeated self-report can influence the awareness and behaviour (Schiffman et al., 2008).

Despite this, the findings carry applied significance. Sustained engagement indicates that brief, low-burden digital interventions are acceptable in real-world contexts. The observed pattern of distress reduction, alongside positive helpfulness ratings suggest potential utility in environments characterised by fluctuating emotional demands.

Importantly, the findings highlight the role of delivery architecture. While threshold-based logic is theoretically sound, effectiveness is contingent on how and when interventions are delivered. Systems reliant on user-initiated engagement are shaped by routine, timing, variability, and competing demands, which may limit temporal precision.

Overall, the results suggest that digital mental health interventions may benefit from aligning delivery mechanisms with user behaviour rather than fixed schedules. Variability in engagement appears to reflect real-world patterns of need and may be informative for future system design. Repeated exposure may also introduce habituation effects, potentially influencing engagement and perceived effectiveness over time.

These findings can be interpreted within Gross's (1998; 2015) Process Model, particularly, the distinction between antecedent-focused and response-focused regulation. The intervention appears to support earlier-stage regulatory processes such as attentional deployment and cognitive reframing, which are associated with more adaptive outcomes. From a methodological perspective, the use of EMA enabled capture of within-person fluctuations in distress, reducing retrospective bias and enhancing ecological validity (Shiffman et al., 2008; Trull & Ebner-Priemer 2013). Addressing limitations of retrospective and between-person designs. However, while the threshold-triggered logic reflects JITAI principles, the system represents a simplified implementation and does not yet incorporate fully adaptive decision rules based on dynamic user data. As such, the present findings should be interpreted as preliminary evidence of feasibility rather than definitive evidence of optimised adaptive intervention.

In sum, this study does not provide conclusive evidence of causal effectiveness but demonstrates that users engage with low-burden digital support and that such engagement is frequently associated with reductions in self-reported distress, providing a foundation for more rigorous evaluation.

4.3 Limitations

Several limitations should be considered when interpreting the findings, which can be grouped into methodological, implementation and measurement-related constraints.

4.3.1 Methodological limitations

The study employed a feasibility-oriented, within-person designed without randomisation or a control condition as such, causal inference cannot be established. Observed reductions in distress may reflect regression to the mean, natural emotional fluctuation, or reactivity to repeated self-monitoring rather than the intervention itself. In addition, the small sample size and variability in response completeness limit generalisability and reduced the stability of observed patterns across individuals.

4.3.2 Implementation and Platform Constraints.

The intervention was delivered within the technical constraints of Gorilla, which limited the extent to which fully adaptive real-time intervention logic could be implemented. Threshold-triggered responses were dependent on self-report input and participant engagement rather than passive sensing or continuous monitoring. Safeguarding thresholds were operationalised with single-instance triggers rather than dynamic or repeated escalation rules, which may have reduced sensitivity to sustained high distress. Furthermore, variability in prompt timing, missed responses and competing demands in participants' daily environments likely influenced when interventions were accessed and how effective they were in practice.

4.3.3 Measurement Limitations

All primary outcomes were based on self-reported, momentary ratings, which are subject to reporting biases and individual differences in scale interpretation. Although EMA reduces retrospective bias, it does not eliminate subjectivity in emotional reporting. In addition, state-level indicators (e.g., distress, clarity, and manageability) were interpreted in relation to broader constructs such as emotion regulation, but do not directly measure underlying regulatory capacity. The absence of objective physiological or behavioural measures further limits the ability to triangulate findings.

4.3.4 Contextual Influences

Importantly, participants' work and daily-role demands were not directly measured but likely played a significant role in shaping engagement patterns. The timing of

EMA prompts, willingness to engage with the intervention and perceived usefulness of support are all likely to be influenced by contextual demands. This suggests that for micro-interventions to be effective in applied settings, including workplace environments, they must remain minimally Intrusive and accessible at the point of need. This is particularly relevant given the applied real-world context of this study and suggests that engagement patterns should be interpreted as context-dependent rather than purely individual-level behaviour.

4.3.5 Implications for Further Research

These limitations highlight the need for more rigorous and context-sensitive evaluation designs. Future research should incorporate controlled or experimental methodologies to enable causal inference, alongside larger and more diverse samples to improve generalisability. Technological development should focus on implementing fully adaptive JITAI systems, incorporating passive data collection and dynamic decision rules to enhance timing precision. Additionally, integrating contextual variables such as workload and environmental demands may improve understanding of when and for whom such interventions are most effective.

4.4 Future Directions

Future research should prioritise the development of fully adaptive intervention systems, App-based infrastructures capable of real-time, state-dependent triggering would improve temporal precision and reduce reliance on participant-initiated engagement. Integration of passive or physiological data streams may further enhance responsiveness.

Findings also highlight the importance of aligning intervention delivery with user behaviour. Future systems could incorporate behaviourally informed personalisation, using early engagement patterns to tailor timing and delivery.

Variability in engagement should be treated as informative rather than noise. Modelling when and under what conditions users engage may improve both intervention targeting and effectiveness.

To establish efficacy, future studies should adopt more rigorous designs, including control conditions, randomisation, and larger samples. The use of within-person statistical models such as mixed-effects approaches, would allow more precise estimation of intervention effects.

Refinement of intervention targeting is also needed. While broad engagement suggests acceptability, more precise triggering mechanisms may improve effectiveness while maintaining optional access for proactive use.

Finally, future work should explore scalability within applied settings such as workplaces, education and clinical services, alongside ethical considerations including data security autonomy and transparency.

4.5 Conclusion

The present study examined the feasibility and behavioural outcomes of a digital micro-intervention delivered within an EMA framework in naturalistic settings. The findings indicate that the system was usable, that participants engaged consistently and that intervention use was associated with reductions in self-reported distress across many instances. These findings should be interpreted as evidence of feasibility and behavioural signal rather than causal effectiveness.

Sustained engagement suggests that brief, structured interventions can be integrated into daily routines, while positive helpfulness ratings indicate perceived utility across emotional contexts.

Overall, the findings demonstrate that low-burden digital interventions are both usable and behaviourally meaningful in real-world contexts. While further refinement and rigorous evaluation are required, the study provides a credible foundation for the development of adaptive, real-time systems to support emotion regulation.

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Appendices

Appendix A. Ethics and Consent Summary

This study received ethical approval from the Nottingham Trent University School of Social Sciences Research Ethics Committee (S3REC).

Participants were provided with a Participant Information Sheet outlining the purpose, procedures, risks, and data handling processes of the study. Participation was voluntary, and participants could withdraw at any time without consequence. Data could be withdrawn up to 14 days post-completion, after which all responses were anonymised and could no longer be linked to individuals.

All participants provided informed consent prior to participation. Consent included confirmation that participants:

- Were aged 18+ or over
- Understood the study procedures
- Understood that the study was not a therapeutic or crisis service

- Understood how their anonymised data would be used

The study did not involve real-time monitoring of responses. Participants were informed that the researcher could not intervene during distress and that the study was not a substitute for clinical support.

Appendix B. EMA Protocol and Timing Logic

Participants completed a 14-day ecological momentary assessment (EMA) protocol delivered via Gorilla.sc.

Day 0 (Onboarding):

- •Participants completed informed consent, eligibility screening, and the baseline DERS-16 measure.

Baseline Phase (Days 1–4):

- One check-in per day at approximately 8:00 a.m.
- EMA items assessed current distress and related state variables.
- No intervention was delivered.

Intervention Phase (Days 5–14):

- Four check-ins per day (morning, midday, afternoon, evening)
- At each check-in, participants completed the same EMA items.

Intervention Trigger:

- When distress was rated ≥6, a micro-intervention screen was automatically presented.
- Participants could proceed through the intervention screen or skip and continue with the task flow.
- Post-intervention items included:
- Distress after the intervention
- Emotional clarity
- Emotional manageability
- Perceived helpfulness

Appendix C. JITAI Trigger Flow (Red Amber–Green Model)

The CalmStack system was implemented as a Just-in-Time Adaptive Intervention (JITAI) embedded within the Gorilla.sc task structure.

Red (Detect):

- Activated when distress reached the intervention threshold (≥6)
- Represents detection of elevated distress rather than failure.

Amber (Reset):

A brief intervention screen was presented automatically.

The intervention included:

- Emotion labelling
- Paced breathing.
- Brief cognitive reframing
- Participants retained autonomy and could continue without fully engaging.

Green (Proceed):

- Participants completed post-intervention ratings and returned to the main EMA flow.

Safeguarding Overlay:

- When distress was rated ≥9, a support signposting screen was displayed.
- Due to platform constraints, this was triggered on a single instance rather than repeated thresholds.
- The intervention screen could still appear within the same interaction sequence.

This structure reflects the practical implementation of a low-burden, real-time digital intervention within platform constraints.

Appendix D. Data Processing and Cleaning Workflow

Data were collected via Gorilla.sc using anonymous participant IDs and exported to secure NTU storage for analysis.

Data preparation involved:

- Merging multiple task-level datasets using a unified identifier (true_person_key)
- Resolving duplicate or fragmented participant IDs
- Removing incomplete or invalid entries
- Constructing analysis-ready datasets

Final sample sizes:

- Total tracked participants: N = 11
- Broad analytical sample: n = 9
- Strict analytical sample: n = 5

The final dataset included approximately 941 intervention events, with all variables standardised and verified prior to analysis.

Appendix E. AI Usage Statement

Generative AI tools were used in a limited and supportive capacity during the preparation of this dissertation.

AI was used to assist with:

- Structuring sections of the document
- Refining clarity and academic expression

- Organising methodological descriptions

AI was not used to:

- Generate or fabricate data
- Conduct statistical analyses
- Interpret results or produce findings

The researcher conducted all analysis, interpretation, and final academic decisions independently. No identifiable participant data were entered into any AI system.

Appendix F. Safeguarding and Distress Protocol

The study included an automated safeguarding procedure embedded within the Gorilla.sc task flow.

- When distress was rated ≥9, an automated support signposting screen was presented.
- This threshold was applied to a single instance of elevated distress due to platform limitations.

The support screen included guidance to:

- GP services
- NTU Student Support
- Samaritans
- NHS 111
- Emergency services (999)

Participants were able to continue with the study after viewing the support screen. The intervention screen could also be presented within the same interaction sequence.

Responses were not monitored in real time, and the study did not provide crisis or therapeutic support.

Appendix G. Recruitment Materials (if retained)

Participants were recruited through opportunity sampling using online and community-facing routes. Recruitment wording emphasised:

- Adults aged 18+ living in the UK.
- Voluntary participation
- Anonymous data collection
- A 14-day stress and emotions study
- Brief digital check-ins
- No payment
- Access to a non-diagnostic personal insight's summary after completion

If retained, this appendix should include the final text-only recruitment wording used in digital or poster-based materials.