

Characterizing behavior change techniques in Mindset: A therapist-guided smartphone intervention for depression

Geneva K. Jonathan, Jenna Y. Sung, Heyli T. Arcese, Phoebe Holz, Kathryn H. Bentley, Emily E. Bernstein, Hilary M. Weingarden, Jennifer L. Greenberg, Oliver T. Harrison, Sabine Wilhelm

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Abstract

Background: Worldwide, depression is a leading cause of disability, and its prevalence continues to rise. Although cognitive behavioral therapy (CBT) is an effective treatment, access to traditional face-to-face CBT is limited due to clinician availability and access barriers. Evidence-based digital interventions offer an alternative, but few document how closely they adhere to established therapeutic protocols. Understanding the content included in these apps helps researchers and clinicians understand mechanisms of action, whether they follow best practices, and how they might be improved.

Objective: This study aims to identify and summarize evidence-based techniques in a validated, commercially available smartphone-based CBT intervention for depression, Mindset.

Methods: Using standardized CBT strategy definitions and the Behavior Change Taxonomy (BCT) version 1 (BCTTv1), we coded all 393 app pages to identify the presence and distribution of therapeutic techniques. Coders used a collaborative consensus process, and interrater agreement was calculated.

Results: All 16 CBT techniques were identified in Mindset, with 528 instances coded across modules. Psychoeducation, skill building, and cognitive restructuring were most frequently applied. BCT coding found 37 of 93 possible techniques across 13 of 16 BCTTv1 categories, with shaping knowledge, repetition and substitution, and feedback and monitoring most prevalent.

Conclusions: Identifying CBT techniques and BCTs in a digital intervention provides transparency about embedded evidence-based strategies and their implementation. Findings show BCTs align with core CBT principles and that complete representation of all BCTs may not be necessary for therapeutic benefit. Using a standardized framework can help describe interventions systematically to support hypothesis generation, evaluation, and refinement.

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Characterizing behavior change techniques in Mindset: A therapist-guided smartphone intervention for depression

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Conclusions: Identifying CBT techniques and BCTs in a digital intervention provides transparency about embedded evidence-based strategies and their implementation. Findings show BCTs align with core CBT principles and that complete representation of all BCTs may not be necessary for therapeutic benefit. Using a standardized framework can help describe interventions systematically to support hypothesis generation, evaluation, and refinement.

Abstract Word Count: 250/250

Keywords Behavioral activation, cognitive behavioral therapy, smartphone intervention, depression, content analysis, behavior change technique

Introduction

Depression is a severe and common illness that affects over 300 million people worldwide, making it one of the leading causes of disability [1, 2]. In recent decades, its prevalence has risen by an estimated 35% [3], increasing the burden on individuals and healthcare systems [4]. Depression substantially lowers quality of life [5], causes significant cognitive impairment [6-8], and places individuals at a higher risk of engaging in suicidal behaviors [4, 9]. Cognitive behavioral therapy (CBT) is one of the most researched and effective treatments for depression, with extensive evidence supporting its ability to reduce depression severity, improve functioning and quality of life [10-12]. However, access to traditional face-to-face CBT is limited due to structural, logistical, and personal barriers, including long waitlists, geographic limitations, time and transportation challenges, high out-of-pocket costs, stigma, and the motivational difficulties inherent to depression [13-17].

Digital interventions, including smartphone-based interventions, have been developed to help overcome barriers to traditional treatment and some have demonstrated effectiveness in delivering CBT [18-21]. Despite substantial evidence supporting digital interventions for depression, many lack precise details about their therapeutic components, making it difficult for users, clinicians, and researchers to evaluate what they involve or how they achieve their intended outcomes [22]. A recent content analysis of popular mental health apps for depression and anxiety reported that most apps incorporated at least one evidence-based component, such as *psychoeducation* or *mindfulness*, but critical techniques like cognitive restructuring and activity scheduling for depression were underrepresented compared to empirically supported treatment protocols [22]. This is especially important as millions of people now turn to digital apps in real-world settings as their primary or only source of mental health support [23].

This lack of specificity contributes to two persistent challenges in digital mental health research: the “black box problem” in which apps demonstrate effectiveness, but the underlying mechanisms remain unclear [24, 25]. and the fidelity problem, where interventions are labeled as “CBT-informed” but their alignment with evidence-based protocols are not well described [24, 25]. Addressing these challenges requires greater transparency and standardization in how digital tools are developed and reported, so that stakeholders can evaluate whether interventions follow evidence-based practices and identify the mechanisms that contribute to clinical change. This aligns with longstanding calls in psychotherapy research to transition from treatment labels to identify mechanisms of change {Kazdin, 2007 #279}, and with process-based approaches that emphasize functional pathways of change over structural fidelity {Hofmann, 2019 #814}.

One way to address these challenges is through the identification of behavior change techniques (BCTs). BCTs are the smallest identifiable, active components of an intervention designed to change behavior, for example, prompting self-monitoring, providing instruction, or encouraging repetition [28]. The BCT taxonomy has been widely applied across digital behavioral domains such as medication adherence [32], physical activity [33, 34], alcohol [29], smoking cessation [35], and condom use [36], and more recently mental health [37-39]. It enables interventions to be described and compared at the level of their smallest active ingredients.

In CBT for depression, therapeutic strategies such as *behavioral activation*, *cognitive restructuring*, or *activity scheduling* are not enacted in the abstract. They are carried out through specific BCTs that make them actionable. For example, *behavioral activation* may be operationalized through BCTs such as *action planning* (supporting users to set meaningful goals), *prompts/cues* (reminding users to follow through), and *self-monitoring* (helping users track and reflect on activity completion). This process-based understanding of psychological interventions [27] makes explicit the behavioral pathways through which therapeutic change occurs and allows researchers to go further than structural fidelity (whether CBT components are present) toward functional fidelity (how they are delivered).

Pairing CBT techniques with BCTs therefore provides critical clinical context. This dual framework allows researchers and clinicians to describe digital intervention content with greater specificity, evaluate fidelity to evidence-based treatment guidelines, and identify gaps or

redundancies in behavioral implementation. In doing so, it moves the field closer to understanding not only what therapeutic strategies are included in digital interventions, but also how they are behaviorally enacted to support change.

This paper presents a secondary analysis of Mindset to address the black box and fidelity challenges in digital mental health. We apply a dual coding approach that pairs CBT techniques with their corresponding BCTs. Mindset has been previously shown to significantly decrease clinician-rated depression severity (large effect size: $d = 1.47$, $p < 0.001$) and improve functional impairment and quality of life, with gains maintained at 3-month follow-up; users also reported moderate to high expectations of benefit and credibility [40]. To better understand how Mindset supports behavior change and to propose a detailed method for evaluating intervention content, we aimed to: (1) identify and describe the CBT techniques embedded in Mindset, (2) label and categorize the BCTs present, and (3) examine how BCTs are distributed across the intervention and used to operationalize CBT strategies. Together, these aims provide a structured analysis of therapeutic content and support greater clarity on how digital CBT for depression enacts change and delivers benefit.

Methods

Mindset Intervention Delivery

Mindset is a therapist-assisted smartphone intervention for depression consisting of eight modules delivered over eight weeks [40]. A detailed description of Mindset's open trial, conducted between May 2022 and February 2023, is available elsewhere [40]. Participants gained access to the intervention immediately after completing baseline assessments. They were instructed to engage with the app independently while attending weekly brief therapist sessions (15-20 minutes) to review progress and receive support.

The intervention includes 393 unique app pages across onboarding content and modules (Table 1), averaging 39.3 pages per module ($SD = 44.8$). Including repeated pages, the app totaled 943 pages. All content is delivered via text, with some pages, particularly the introductory module and mindfulness exercises, also available in video format. The intervention begins with an overview (onboarding pages) of CBT for depression and how to use the program (Table 1). Module 1 could be completed at the participant's own pace; subsequent modules (Modules 2–8) required a minimum of seven days to reinforce skill practice and integration.

During Module 2, participants were prompted to log at least three activities they engaged in and corresponding moods daily. Beginning in Module 3, participants began behavioral activation (BA), with access to a list of 102 suggested activities, categorized into seven core values: health and wellness, causes and community, spirituality, creative pursuits, career and education, personal relationships, and day-to-day tasks. Each participant was instructed to schedule at least three weekly activities and log their mood after completion. This activity scheduling feature continued through Modules 4-8.

Table 1 Mindset intervention overview, module-by-module.

Module	Description	Pages (#)		Total
		Unique	Repeated	
Onboarding	Introduction to intervention and how to use	10	0	10
Module 1: Exploring How We Think	Cognitive restructuring to challenge unhelpful thinking	135	0	135
Module 2: Activities and Mood	Self-monitoring of activities and associated moods	28	0	28
Module 3: Goals and Scheduling	Identify personal values, set goals, scheduling activities aligned with priorities	24	7	31
Module 4: Establishing a Rhythm	Mindful breathing, continued scheduling of activities	19	7	26
Module 5: Keeping Momentum	Mindful grounding, continued scheduling of activities	9	7	16
Module 6: Planning Around Priorities	Skills to let go of unhelpful thoughts, continued scheduling of activities	9	7	16
Module 7: Examining Core Beliefs	Modification of core beliefs and building self-esteem, continued scheduling of activities	26	7	33
Module 8: Preparing for the Future	Relapse prevention, reflect on progress and learned skills, continued scheduling of activities	23	7	30
Total		283		325

We used a dual-coding approach that systematically identified both the therapeutic strategies present in Mindset and the specific behavioral mechanisms through which they are delivered. This approach pairs established CBT technique definitions with the Behavior Change Taxonomy (BCTTv1) [28] to describe what therapeutic content is included, and how it is behaviorally operationalized, what we term 'mechanism mapping.'

We first identified and labeled CBT techniques present in Mindset to determine which therapeutic strategies were included and to evaluate alignment with established CBT protocols for depression (Table 2). The CBT coding framework consisted of 16 techniques most commonly found in manualized CBT protocols, including *psychoeducation*, *homework*, *cognitive restructuring*, *behavioral activation*, *problem solving*, and *relapse prevention* [22, 41]. Techniques were coded based on the presence of explicit content, exercises, or instructions; implied techniques were not coded.

We applied the Behavior Change Taxonomy (BCTTv1), a validated framework comprising 93 techniques, organized into 16 hierarchically clustered categories[28, 42, 43]. These categories span the full spectrum of behavior change mechanisms, from goal setting and self-monitoring to environmental restructuring and identity change. Each technique is defined with examples to support reliable coding and evaluation. The first author (GKJ) was trained in using BCTTv1 through the official online training platform (www.bct-taxonomy.com). The 16 categories and their definitions are fully described by Michie et al. [28].; Table 3 presents the specific BCTs identified in Mindset with their operational definitions and examples of implementation.

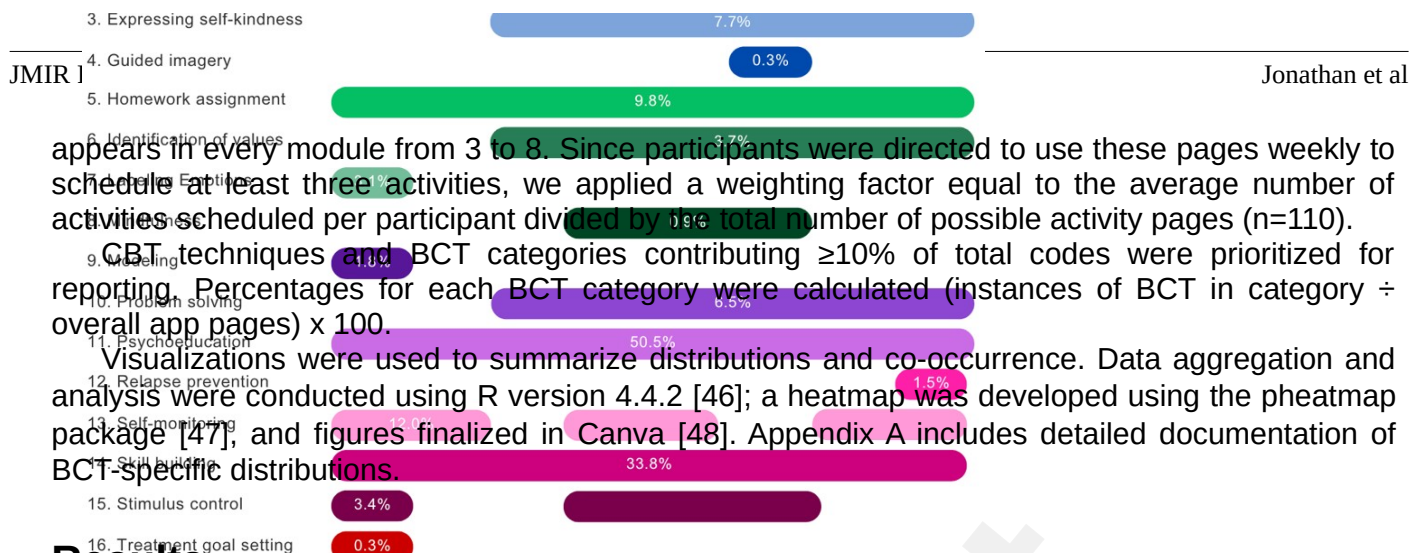
Before coding, the raw text of the Mindset app was organized by individual intervention pages to reflect their original placement in the app. This ensured accurate tracking of where each piece of content appeared and preserved the intervention's structure during coding. A collaborative coding approach was used to identify CBT techniques and BCTs [44].

Analysis

Coding frequencies were aggregated to examine the distribution of CBT techniques and BCTs across the Mindset intervention. The frequency and total number of CBT techniques and BCTs applied were calculated. Then we calculated the mean number of applications (m), standard deviation (SD), and range (maximum-minimum). To prevent repeated content from inflating counts, intervention pages that were revisited multiple times were weighted by expected participant use. For

Figure 1. Distribution of CBT elements across Modules 1–8 of the Mindset app. Percentages represent the proportion of total intervention pages (N=325) that included each CBT element.

https://preprints.jmir.org/preprint/84030	MODULE								[unpublished, non-peer-reviewed preprint]
CBT CATEGORY	1	2	3	4	5	6	7	8	
1. Activity scheduling	12.9%								



appears in every module from 3 to 8. Since participants were directed to use these pages weekly to schedule at least three activities, we applied a weighting factor equal to the average number of activities scheduled per participant divided by the total number of possible activity pages (n=110).

CBT techniques and BCT categories contributing $\geq 10\%$ of total codes were prioritized for reporting. Percentages for each BCT category were calculated (instances of BCT in category $\div$ overall app pages) $\times 100$.

Visualizations were used to summarize distributions and co-occurrence. Data aggregation and analysis were conducted using R version 4.4.2 [46]; a heatmap was developed using the pheatmap package [47], and figures finalized in Canva [48]. Appendix A includes detailed documentation of BCT-specific distributions.

Results

CBT Techniques

The Mindset app included all 16 CBT techniques (100%), applied 528 times (M=66.0, SD=56.0) across modules (Figure 1; Table 2).

High-frequency techniques ($\geq 10\%$)

Psychoeducation was the most common, present on 50.5% of app pages (n=164 M = 20.5, SD=23.1). It appeared in all modules, but nearly half of all instances occurred in Module 1, which accounted for nearly half (46.3%, n=76) of all *psychoeducation* instances. *Skill building* was the second most frequent, on 33.8% of pages (n = 110; M = 13.8, SD = 12.9), again most concentrated in Module 1 (40.9%, n = 45). *Cognitive restructuring* appeared on 14.2% of pages (n = 46; M = 23.0, SD = 21.2), confined to Modules 1 (n = 38) and 7 (n = 8). *Activity scheduling* accounted for 12.9% (n = 42), implemented consistently across Modules 3–8 (M = 7.0, SD = 0.0). *Self-monitoring* was present on 12.0% (n = 39; M = 5.6, SD = 13.8), distributed across six modules (1–2, 4–5, 7–8).

Low-frequency techniques ($< 10\%$)

Expressing self-kindness, homework assignments, problem solving, and identification of values each accounted for 3–10% of intervention pages, while guided imagery, labeling emotions, mindfulness, modeling, relapse prevention, stimulus control, and treatment goal setting each accounted for $< 5\%$. Frequencies and module distributions for these techniques are reported in Appendix A.

Table 2 Cognitive behavioral strategy definitions and examples of implementation in Mindset

CBT Strategies	Definition	Examples of Implementation in Mindset
Activity scheduling	Identifying activities that the individual finds pleasant or mood-elevating, and subsequently scheduling some of those activities, with the goal of promoting or maintaining involvement in satisfying and enriching experiences.	- Log three activities/day to observe influence on mood - Schedule valued activities - Check schedule to see if there is enough time for the activity
Cognitive restructuring	Techniques that modify interpretation of events by examining thoughts and generating alternative counter-statements, sometimes paired with exercises that test the validity of the original versus alternative thoughts through using relevant information.	- Identify a negative thought/belief and develop a more balanced perspective - Explore alternative ways of thinking
Expressing self-kindness	Encouraging and guiding individuals to be kind to themselves, often through considering good personal qualities and evidence of their strengths, or by encouraging self-forgiveness or acceptance for perceived flaws and mistakes.	- Write an encouraging note to self - Write a balanced perspective about self - Identify and list positive qualities of self
Guided imagery	Visualizing images (e.g., beach, ocean) or situations (e.g., giving a good presentation) to promote relaxation, increase self-awareness, or	- Visualize placing each thought on a cloud and watching it drift away

Homework assignment	mentally rehearse adaptive behaviors. Structured tasks for users to complete outside the app/session to improve treatment adherence and consolidate learning.	- Direction to log an activity at least once a day
Identification of values	Identifying values, or the things that are most important to a person (e.g., kindness, family, learning), usually also involves considering ways in which a person can better live up to their values.	- Select activities or goals aligned with personal values
Labeling emotions	Guidance or activities to help individuals identify emotional states, sometimes includes a prompt to consider why they are feeling that way in order to identify triggers.	- Encouraged to reflect on and name what one might feel after a challenging situation (i.e. job interview) - Negative thoughts can make you feel discouraged or hopeless
Mindfulness	Activities to help build non-judgmental, present-focused awareness.	- Bring attention to breath - Notice thoughts when they occur
Modeling	Demonstration of a desired behavior to promote imitation and performance of that behavior	- Example of positive thinking pattern - Demonstration of how to set a SMART goal
Problem solving	Identifying problems and developing solutions to manage life challenges and stressors.	- Identify barriers to planned activities - Evaluate if current goals and activities align with values
Psychoeducation	Provision of information about mental health symptoms or the treatment process (e.g., session frequency/content) to increase the likelihood that users will be prepared for and participate in treatment.	- Changes in seasons can lead to low mood - Consistent practice of CBT techniques can improve mood and functioning
Relapse prevention	Strategies designed to help individuals anticipate, identify, and manage high-risk situations that may lead to setbacks in progress (e.g., identifying warning signs, developing coping strategies, creating action plans).	- Make a plan for anticipated stressful events
Self-monitoring	Monitoring one's thoughts, behaviors, physical sensations, and/or emotions.	- Reflect on behaviors/feelings in the current moment - Notice thoughts when they occur
Skill building	Imagined and actual rehearsal of a therapeutic skill to build/reinforce competence in a skill.	- Knowledge quizzes to reinforce understanding (e.g., identifying catastrophizing or fortune-telling thoughts). - Log three activities/day to observe influence on mood
Stimulus control	Managing stimuli to promote behavior change, such as removing triggers from the environment.	- Identify behaviors or thoughts that trigger negative emotions - Turn off notifications while practicing mindfulness
Treatment goal setting	Establishing long-term goals (usually at the beginning of treatment).	- Set goal in alignment with values

Behavior Change Techniques

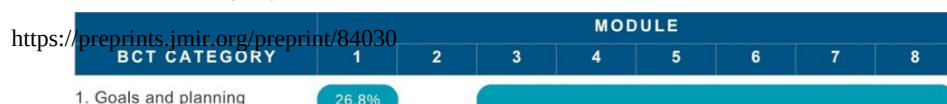
The intervention included 37 BCTs (39.8% of the taxonomy), drawn from 13 of 16 categories and applied 878 times ($M = 109.8$, $SD = 92.0$) across modules (Figure 2; Table 3).

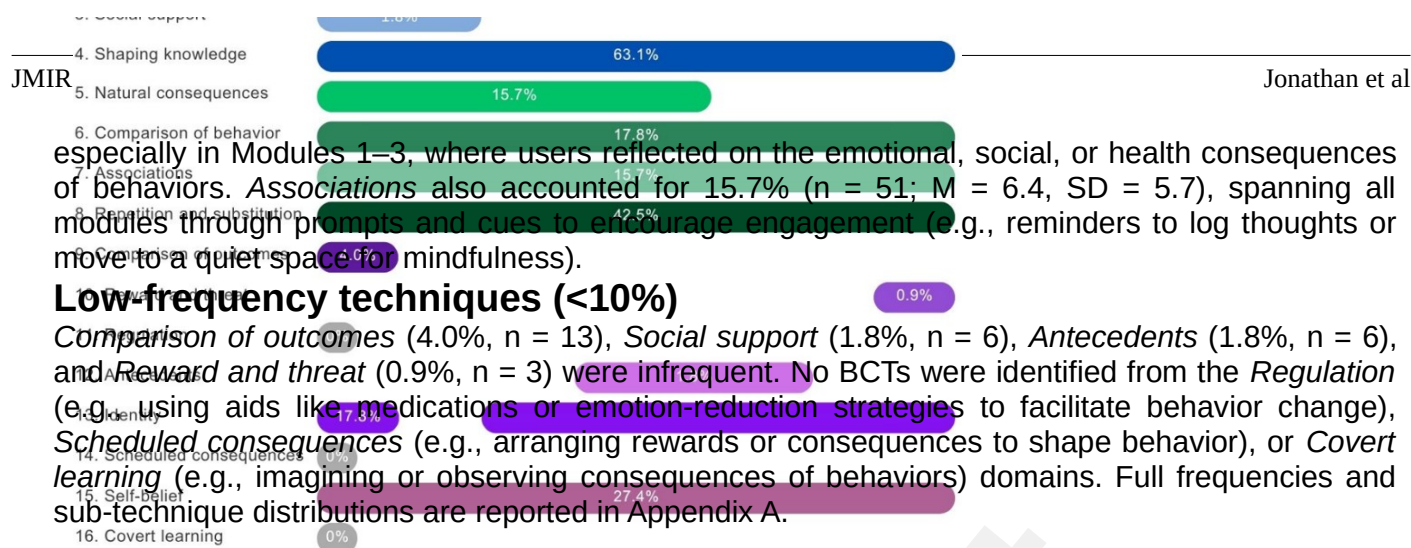
High-frequency techniques ($\geq 10\%$)

Shaping knowledge was the most frequent, appearing on 63.1% of pages ($n = 205$; $M = 25.6$, $SD = 22.5$). This category included *instruction on how to perform a behavior* (43.1%, $n = 140$) and *information about antecedents* (20.0%, $n = 65$), concentrated in Modules 1 and 3. *Repetition and substitution* appeared on 42.5% of pages ($n = 138$; $M = 17.3$, $SD = 13.9$), most common in Modules 1 ($n = 51$) and 7 ($n = 18$), where users practiced identifying negative thinking traps or examining core beliefs. *Feedback and monitoring* accounted for 34.8% of pages ($n = 113$; $M = 14.1$, $SD = 12.4$), concentrated in Modules 1–2, where users logged mood and reflected on progress. *Self-belief* appeared on 27.4% ($n = 89$; $M = 11.1$, $SD = 11.0$), with the largest proportion in Module 1 (39%, $n = 35$), encouraging recognition of coping skills and prior accomplishments. *Goals and planning* occurred on 26.8% ($n = 87$; $M = 10.9$, $SD = 6.1$), spanning all modules except Module 2, with the highest counts in Module 8 ($n = 18$) during relapse-prevention planning. Identity accounted for 17.8% ($n = 58$; $M = 7.3$, $SD = 12.2$), more than half of which occurred in Module 1 (60.3%, $n = 35$). *Comparison of behavior* was also present in 17.8% ($n = 58$; $M = 7.3$, $SD = 5.4$), primarily in Modules 1 and 3, where users reframed negative thoughts by considering what advice they would

give a friend. *Natural consequences* appeared on 15.7% of pages ($n = 51$; $M = 6.4$, $SD = 10.8$),

Figure 2. Distribution of BCT categories across Modules 1–8 of Mindset. Percentages represent the proportion of total intervention pages ($N=325$) that included at least one BCT from each category.





especially in Modules 1–3, where users reflected on the emotional, social, or health consequences of behaviors. *Associations* also accounted for 15.7% ($n = 51$; $M = 6.4$, $SD = 5.7$), spanning all modules through prompts and cues to encourage engagement (e.g., reminders to log thoughts or move to a quiet space for mindfulness).

Low-frequency techniques (<10%)

Comparison of outcomes (4.0%, $n = 13$), *Social support* (1.8%, $n = 6$), *Antecedents* (1.8%, $n = 6$), and *Reward and threat* (0.9%, $n = 3$) were infrequent. No BCTs were identified from the *Regulation* (e.g., using aids like medications or emotion-reduction strategies to facilitate behavior change), *Scheduled consequences* (e.g., arranging rewards or consequences to shape behavior), or *Covert learning* (e.g., imagining or observing consequences of behaviors) domains. Full frequencies and sub-technique distributions are reported in Appendix A.

CBT and BCT co-occurrence

Beyond documenting presence and frequency, we examined the mechanistic relationships between therapeutic strategies and their behavioral implementations. This analysis addresses the call to identify mechanisms of change by demonstrating which behavioral pathways support each therapeutic technique [26]. To accomplish this, we examined the co-occurrence of CBT techniques and BCT categories (Figure 4). The heatmap demonstrates CBT techniques varied substantially in their overlap with BCT categories.

Psychoeducation showed the largest overlap, co-occurring with all 13 observed BCT categories, most frequently with *Shaping knowledge* ($n = 119$). *Skill building* was also widely scaffolded, aligning most often with *Repetition and substitution* ($n = 114$), *Feedback and monitoring* ($n = 83$), and *Shaping knowledge* ($n = 80$). *Activity scheduling* co-occurred with seven categories, most prominently *Goals and planning*, *Repetition and substitution*, and *Associations*.

By contrast, *cognitive restructuring*, *self-monitoring*, and *problem solving* were supported by fewer BCT categories (typically 3–5), and techniques such as *mindfulness*, *guided imagery*, and *relapse prevention* showed limited overlap, each linked with no more than two categories.

Across the intervention, overlaps were concentrated in a small number of BCT categories, *Shaping knowledge*, *Repetition and substitution*, *Feedback and monitoring*, and *Goals and planning*, which together accounted for most behavioral implementation. Other categories such as *Reward and threat*, *Social support*, *Comparison of outcomes*, and *Antecedents* were rarely applied, and none were drawn from the *Regulation*, *Scheduled consequences*, or *Covert learning* domains.

Table 3 Behavior change technique definitions and examples of how implemented in Mindset

#	BCT	Definition*	Examples of Implementation in Mindset
1.	Goals and planning	Setting and reinforcing behavior-related goals	
1.1	Goal setting (behavior)	Set/agree on a goal defined for behavior to be achieved	-Select weekly behavioral goals -Setting intentions for use of Mindset
1.2	Problem solving	Analyze/prompt to analyze factors influencing the behavior and generate/select strategies to overcome barriers and/or increase facilitators	- Check calendar to see if there is time for the activity - Identify barriers to planned activities
1.3	Goal setting (outcome)	Set/agree on goal defined in terms of a positive outcome of wanted behavior	- Set goal in alignment with values
1.4	Action planning	Prompt planning of the behavior	- Schedule valued activities - Make a plan for anticipated stressful events
1.5	Review behavior goal(s)	Review behavior goal(s) jointly and consider modifying goal(s) or behavior change strategy in light of achievement	- Reflect on behavior's impact on mood, make adjustments as needed
1.6	Discrepancy between current behavior and goal	Draw attention to discrepancies between current behavior and previously set outcome goals, behavioral goals or action plans	- Reflect on how current behaviors (e.g., avoidance) differ from goals (e.g., engagement in valued activities)
1.7	Review outcome goal(s)	Review outcome goal(s) and consider modifying goal(s) in light of achievement	- Reflect whether goals for Mindset yielded expected outcomes
1.9	Commitment	Ask the person to affirm/reaffirm statements indicating commitment to change the behavior	- Encourage saving planned activities in app
2.	Feedback and monitoring	tracking progress through self-monitoring, observation, or devices, with optional feedback	

2.1	Monitoring of behavior by others without feedback	Observe or record behavior with the person's knowledge as part of a behavior change strategy	- Prompt that therapist will be able to see what the user is logging
2.2	Feedback on behavior	Monitor and provide informative/evaluative feedback on performance of the behavior	- Feedback cognitive restructuring quiz responses (e.g., "Great job"/"Nice try")
2.3	Self-monitoring of behavior/thought	Establish method to monitor/record their behavior(s) as part of a behavior change strategy	- Feedback on core beliefs
2.4	Self-monitoring of outcome(s) of behavior	Establish method to monitor/record the outcome(s) of their behavior as part of a behavior change strategy	- Reflect on behaviors/feelings in the current moment
2.7	Feedback on outcome(s) of behavior	Monitor and provide feedback on the outcome of performance of the behavior	- Notice thoughts when they occur
3.	Social support	providing practical, emotional, or general support	- Reflect how Mindset impacted mood and well-being
3.1	Social support (unspecified)	Advise on, arrange/provide support or noncontingent praise/reward for performance of the behavior	- Evaluate how completed activities affected mood/well-being
3.2	Social support (practical)	Advise on, arrange, or provide practical help for performance of the behavior	- "Your therapist can view logged activities."
3.3	Social support (emotional)	Advise on, arrange, or provide emotional social support for performance of the behavior	- Send messages to ask therapist how to use Mindset
4.	Shaping knowledge	guiding correct behavior, identifying antecedents, and exploring causes of undesired behavior	- Enable notifications to stay motivated
4.1	Instruction on how to perform the behavior	Advise or agree on how to perform the behavior	- Access resources like 911 or 988 in emergencies
4.2	Information about antecedents	Provide information about antecedents (e.g. social/environmental situations and events, emotions, cognitions) that reliably predict behavior	- Connect with therapist for guidance and support.
5.	Natural consequences	providing information on health, social, or emotional impacts of undesired behavior	- Direction to log an activity at least once a day
5.1	Information about health consequences	Provide information (e.g. written, verbal, visual) about health consequences of performing the behavior	- Instruction to plan activities by checking schedule/anticipating barriers
5.3	Information about social and environmental consequences	Provide information (e.g. written, verbal, visual) about social/environmental consequences of performing the behavior	- Changes in seasons can lead to low mood
5.6	Information about emotional consequences	Provide information (e.g. written, verbal, visual) about emotional consequences of performing the behavior	- Negative thoughts can make you feel more discouraged
6.	Comparison of behavior	Modeling correct behavior and using feedback from others	- Consistent practice of CBT techniques can improve mood and functioning
6.1	Demonstration of the behavior	Provide an observable sample of the behavior, directly or indirectly (e.g. via film, pictures to aspire to/ imitate)	- Preoccupation with negative thoughts can disconnect you from the present
6.2	Social comparison	Draw attention to others' performance of behavior to allow comparison with the person's own performance	- Low mood may lead to social interaction avoidance (e.g., ignoring calls from friends/family)
7.	Associations	Using prompts or cues to support desired behavior and reduce undesired behavior	- Negative thoughts may make you discouraged or even hopeless
7.1	Prompts/cues	Introduce/define environmental or social stimulus to prompt or cue the behavior	- Example of negative thinking patterns
8.	Repetition and substitution	Practicing desired behavior to replace undesired behavior	- Demonstration of how to set a SMART goal
8.1	Behavioral practice/rehearsal	Prompt practice/rehearsal of the behavior one or more times in a context or at a time when the performance may not be necessary, to increase habit and skill	- Describe another person and select their characteristics from a list
8.2	Behavior substitution	Prompt substitution of the unwanted behavior with a wanted or neutral behavior	- Recognize moments of comparison (e.g., noticing friends seem to have more fun while overlooking own enjoyable experience)
8.3	Habit formation	Prompt rehearsal/repetition of the behavior in the same context repeatedly so that context elicits the behavior	- Encourage to return to Mindset to refresh skills
8.6	Generalization of target behavior	Advise to perform the wanted behavior, which is already performed in a particular situation, in another situation	- Reach out to therapist
8.7	Graded tasks	Set easy-to-perform tasks, making them increasingly difficult, but achievable, until behavior is performed	- Log three activities/day to observe influence on mood
9.	Comparison of outcomes	Evaluating pros and cons of undesired behavior, often with expert input	- Knowledge quizzes to reinforce understanding (e.g., identifying catastrophizing or fortune-telling thoughts).
9.1	Credible source	Present verbal or visual communication from a credible source in favor of or against the behavior	- Write a balanced belief about self
10.	Reward and threat	Using rewards or incentives to encourage behavior	- Acknowledge unhelpful thoughts and let them pass without evaluation.

10.9	Self-reward	Prompt self-praise or self-reward if and only if there <i>has been</i> effort and/or progress in performing the behavior	- Reflect on progress since starting Mindset - Acknowledge how far you've come and skills gained to manage depression
12.	Antecedents	Modifying the environment to support desired behavior	
12.1	Restructuring the physical environment	Change/advise to change physical environment to facilitate wanted behavior or create barriers to unwanted behavior	- Finding a quiet place/enabling 'do not disturb' to reduce distractions during mindfulness exercise
12.6	Body changes	Alter body structure, functioning or support directly to facilitate behavior change	- Bring attention to breath - Bring attention to tension in body
13.	Identity	Changing self-identity to align with desired behavior	
13.1	Identification of self as role model	Inform that one's own behavior may be an example to others	- Reflect on personal strengths and achievements
13.2	Framing/reframing	Suggest adoption of a perspective or new perspective on behavior to change cognitions or emotions about performing the behavior	- Identify negative thought and develop a more balanced perspective
13.3	Incompatible beliefs	Draw attention to discrepancies between current or past behavior and self-image, to create discomfort	- Explore alternative ways of thinking - Recognize negative beliefs and reframe them with a balanced perspective
13.4	Valued self identity	Advise to write/complete rating scales about a cherished value/personal strength to affirm the person's identity as part of a behavior change strategy	- Select activities or goals aligned with personal values - Choose positive qualities about self from a provided list
13.5	Identity associated with changed behavior	Advise to construct a new self-identity as someone who 'used to engage with the unwanted behavior'	- Identify and list positive qualities about self
15.	Self-belief	building confidence through self-talk, encouragement, or reflection on past success	
15.1	Verbal persuasion about capability	Tell user they can successfully perform wanted behavior, arguing against self-doubts/asserting they can and will succeed	- "The more you practice, the easier and more natural it will become" - "You're well-equipped to handle future challenges"
15.3	Focus on past success	Advise to think about or list previous successes in performing the behavior (or parts of it)	- Write about skills you've gained - Recognize progress in spotting and addressing unhelpful thoughts
15.4	Self-talk	Prompt positive self-talk (aloud or silently) before/during the behavior	- Write an encouraging note to self - Write a balanced perspective about self

*Definitions from Michie et al. (2013), BCTTv1[28]

Discussion

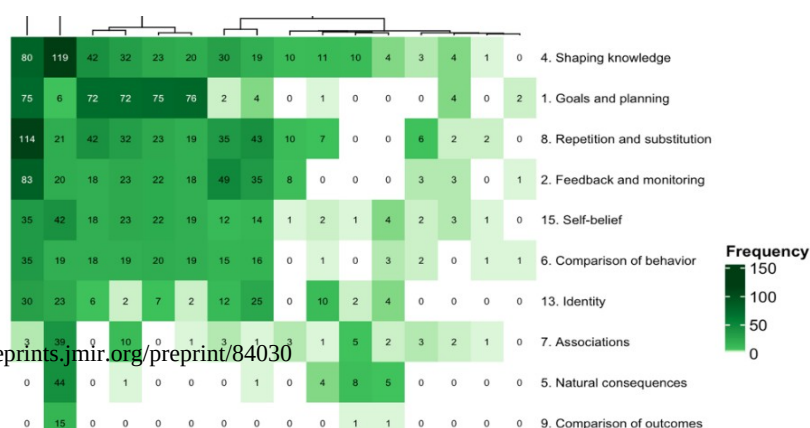
This study introduces a systematic, page-level mechanism mapping method that links CBT techniques to their behavioral enactments (BCTs) in a digital intervention. This approach extends prior work that catalogued which techniques are present or not present [22] by showing *how* therapeutic change is behaviorally enacted, directly addressing the longstanding calls in psychotherapy research to identify mechanisms of change [Kazdin, 2007 #279] and operationalizing the process-based perspective that emphasizes functional pathways over structural fidelity [27].

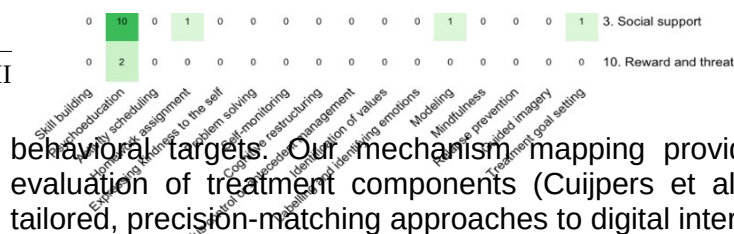
The co-occurrence analysis illustrates the value of this approach. While the intervention followed the expected CBT progression, techniques that were presented earlier in the app such as psychoeducation and skill building received substantially more behavioral scaffolding than later techniques like relapse prevention and mindfulness, a pattern that would remain invisible without mechanism mapping. This differential support may help account for the "engagement cliff" phenomenon, where users disengage after the first few weeks of use [Boucher, 2024 #815]. For clinicians, this findings offer an approach to identifying points in the intervention where human

support may add the most value [Mohr, 2017 #816].

Our observation that only 39.8% of possible BCTs were represented challenges the field's "kitchen sink" approach to app design, the assumption that including more features and techniques improves clinical outcomes. This design philosophy may paradoxically reduce effectiveness through choice overload and diluted user attention across competing

Figure 3. Co-occurrence heatmap of CBT treatment elements and Behavior Change Techniques (BCTs) in the Mindset app. The frequency that each CBT treatment element (columns) co-occurred with specific BCTs (rows) across 325 app pages. Darker shades indicate higher co-occurrence frequencies.





behavioral targets. Our mechanism mapping provides the measurement precision needed for evaluation of treatment components (Cuijpers et al., 2019) and lays the groundwork for more tailored, precision-matching approaches to digital intervention design.

Although the BCT framework has been widely applied in behavioral health [50, 51], its use in mental health interventions is limited [38] even though these interventions incorporate elements of behavior change. Prior reviews of digital health apps typically identified far fewer BCTs per intervention (often 8 to 14) [39, 52, 53], likely because these studies depended on developer descriptions rather than page-level coding, limiting visibility into mechanism delivery.

A review of depression apps, for example, reported the presence of techniques such as *psychoeducation*, *self-monitoring*, *cognitive restructuring*, *mindfulness*, and *activity scheduling* {Wasil, 2019 #735}. Our analysis confirms that these elements are present in Mindset but extends prior work by specifying how they were behaviorally enacted. For instance, *psychoeducation* was not limited to providing general information; it also included instructions for mindfulness practice and explicit links between behavior and health or social consequences. This illustrates that the same CBT technique can be delivered through different behavioral pathways, which may raises the hypothesis that variability in effectiveness across apps labeled as “CBT-informed” apps may reflect differences in behavioral enactment. To our knowledge, no prior study has visualized the overlap between CBT strategies and their behavioral enactments in digital mental health. The heatmap provides a transparent way to identify implementation gaps, such as under-scaffolded relapse prevent, that would otherwise go unnoticed in aggregate coding.

Limitations

Thought our mechanism mapping approach advances the evaluation of digital CBT fidelity, several limitations warrant consideration. First, this study descriptively outlined evidence-based techniques embedded within the Mindset intervention but did not statistically link participants’ exposure to these techniques with clinical outcomes. Without direct measures of cognitive or behavioral change (e.g., frequency of mindfulness practice or scheduled activities), the degree to which specific techniques influenced outcomes remains unknown. Second, our text-based coding may underestimate exposure to intervention components delivered through other modalities, such as video, audio, or interactive features. For example, mindfulness exercises presented in video format likely involved greater engagement than suggested by their text-based representation. Future work will benefit from multimodal measurement strategies that more fully capture diverse content delivery methods. Third, our collaborative coding process, while ensuring thorough coverage and discussion, may have introduced subjective biases. Even with formal BCT taxonomy training, categorizing digital intervention content inevitably involves judgment, which can affect coding consistency. Fourth, Mindset is designed for use alongside abbreviated psychotherapy sessions, yet therapist-delivered content was excluded from our analysis. This decision limited our focus to standardized digital components and may underrepresent the total therapeutic exposure available to users. Finally, our analysis concentrated exclusively on evidence-based CBT techniques and behavior change strategies, without assessing non-evidence-based or potentially contraindicated content. Because some mental health apps include elements that may conflict with recommended approaches, future fidelity frameworks should account for both evidence-based and potentially non-recommended strategies to provide a more comprehensive evaluation of intervention quality and safety. These limitations highlight that mechanism mapping should be considered a first step toward a broader framework for fidelity evaluation, rather than a definitive account of therapeutic exposure.

Future Directions

This study provides a step toward understanding the relationship between the content of a smartphone intervention for depression and clinical/functional outcomes. Incorporating measures of cognitive changes (e.g., validated scales like the Cognitive Behavioral Avoidance Scale {Ottenbreit, 2004 #767}), behavioral tracking (e.g., digital activity logs), and identified mechanisms of action

(e.g., skill acquisition or knowledge retention) could enable mediation analyses to clarify which treatment elements are drivers of therapeutic change. Additionally, the limited representation of certain BCT categories, particularly social support, provides opportunities for further exploration. For instance, research indicates that social support can reduce the risk of depression relapse [54], increase treatment adherence, and improve outcomes [55-57]. However, this BCT category was not prominently featured in this intervention. Moreover, the therapist-guided calls embedded within Mindset represent a significant yet untapped resource for understanding how human-delivered BCTs complement digital content. Future studies should systematically code therapist interactions to clarify the complementary roles of technology and therapist support. Ultimately, combining digital and therapist-delivered components could inform the development of hybrid interventions.

Conclusions

This study provides transforms a 'black box' into a 'glass box' and offers the field what it has been seeking: a replicable method for understanding not just whether digital CBT works, but how. The mechanism mapping approach we introduce offers a path toward the precision, transparency, and scientific rigor that will determine whether digital mental health fulfills its promise of scalable, effective treatment. As these interventions become first-line treatments for millions globally, such mechanistic understanding it is essential for ethical, effective clinical practice.

Conflicts of Interest

Dr. Jonathan has received research support from the National Institute on Drug Abuse. Dr. Wilhelm is a presenter for the Massachusetts General Hospital Psychiatry Academy in educational programs supported through independent medical education grants from pharmaceutical companies. She has received royalties from Guilford Publications, New Harbinger Publications, Springer, and Oxford University Press. Dr. Wilhelm has also received speaking honoraria from various academic institutions and foundations, including the International Obsessive Compulsive Disorder Foundation, the Tourette Association of America, and the Centers for Disease Control and Prevention. In addition, she received honoraria for her role on the Scientific Advisory Board for One-Mind (PsyberGuide), Koa Health Digital Solutions LLC, and Noom, Inc. Dr. Wilhelm has received research support from Koa Health Digital Solutions LLC. Dr. Weingarden receives salary from HabitAware, Inc, has been a paid consultant to APA Labs and Hello Therapeutics, Inc., is a paid scientific advisory board member for Augmend Health, and has received research support from National Institute of Mental Health, Koa Health, LLC, and President and Fellows of Harvard College. Dr. Bentley is a paid consultant to Visible Health Inc., and has received research support from the National Institute of Mental Health. Dr. Harrison is Founder and CEO of Koa Health Limited, and receives reimbursement as the Royal Society Entrepreneur in Residence in healthcare AI at Oxford University.

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Abbreviations

BA: behavioral activation

BCT: behavior change technique

BCTTv1: Behavior Change Taxonomy version 1

CBT: cognitive behavioral therapy

SMART goals: specific, measurable, achievable, relevant, and time-bound goal

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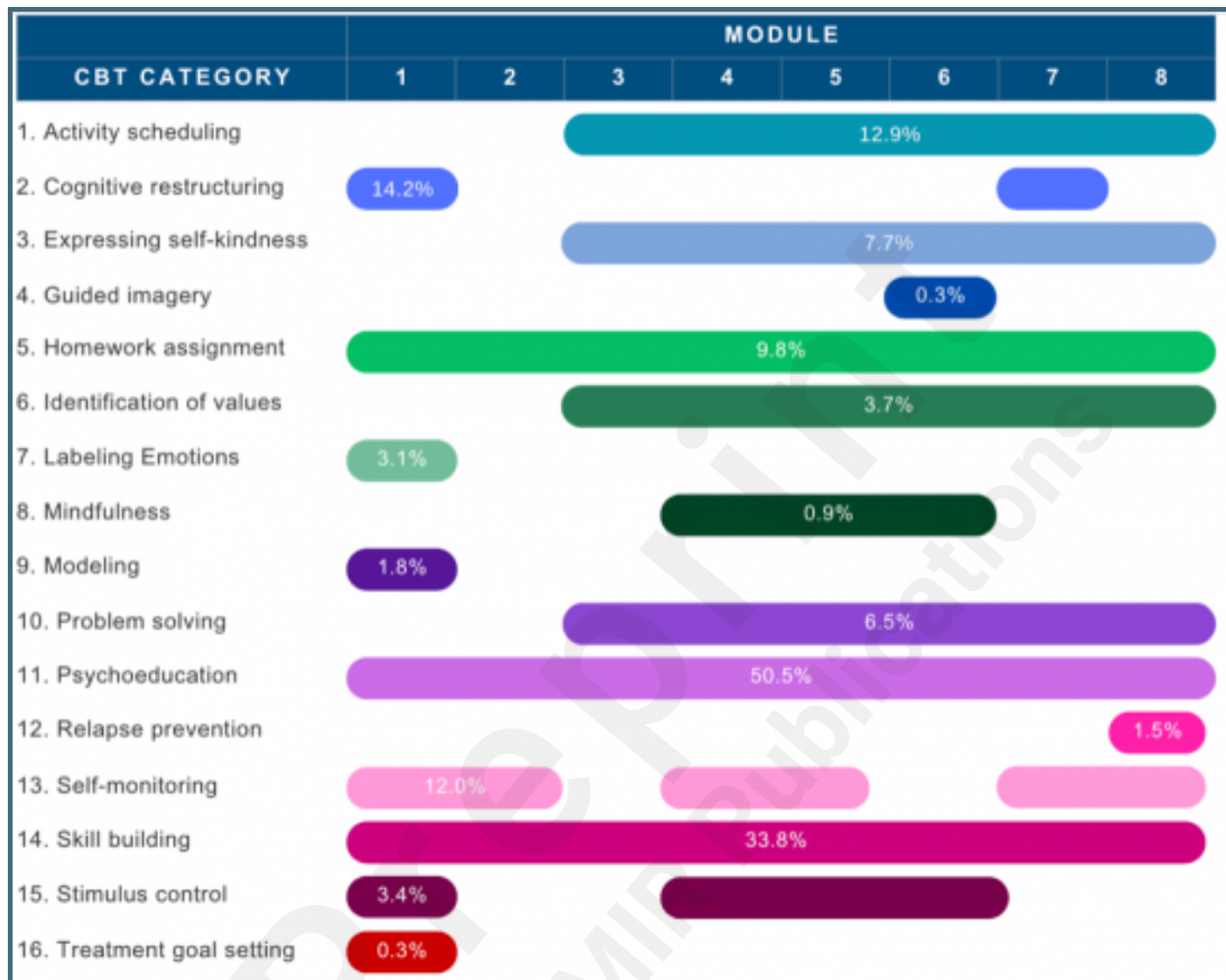
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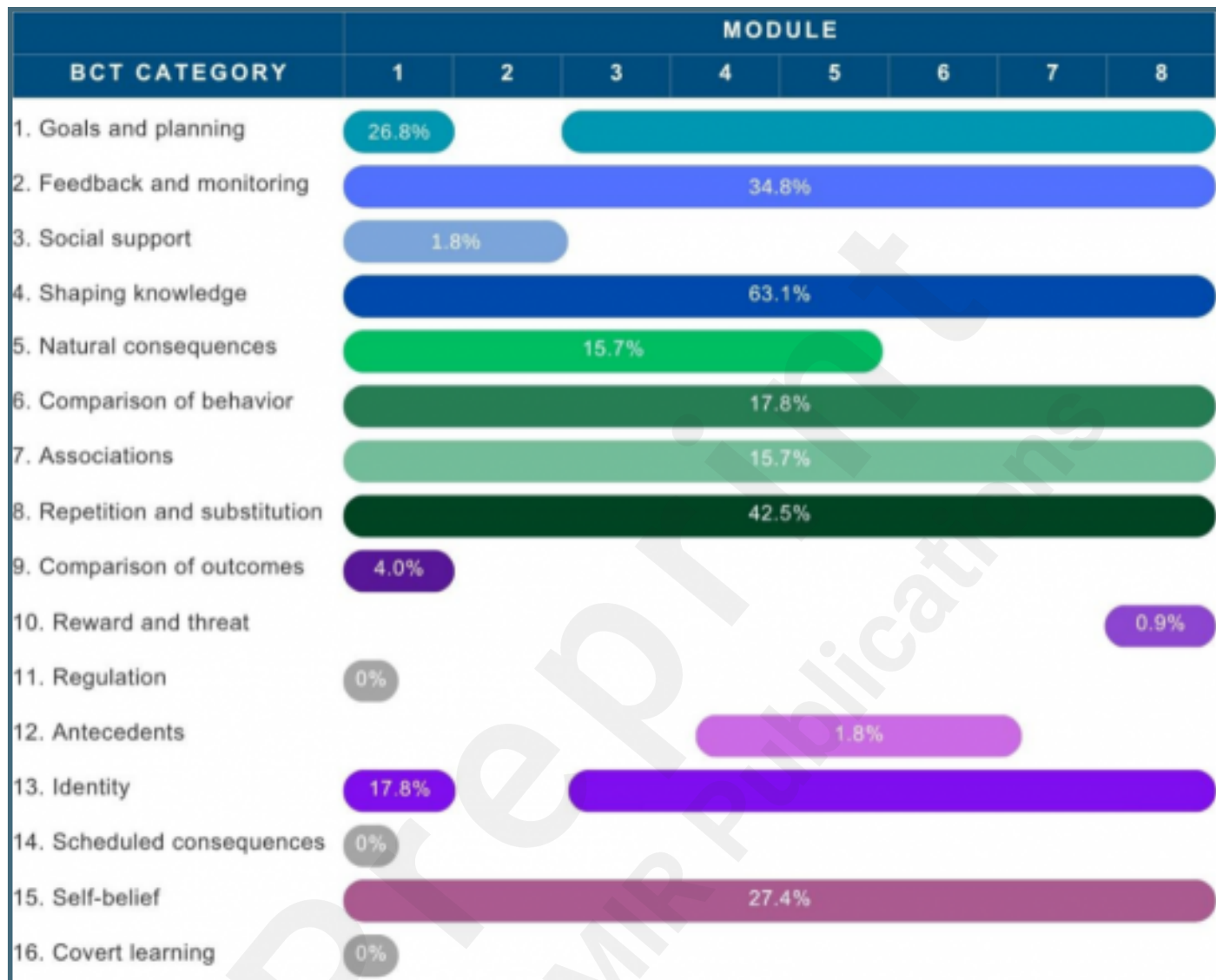
Supplementary Files

Figures

Distribution of CBT elements across Modules 1-8 of the total Mindset app. Percentages represent the proportion of total intervention pages (N=325) that included each CBT element.



Distribution of BCT categories across Modules 1-8 of Mindset. Percentages represent the proportion of total intervention pages (N=325) that included at least one BCT from each category.



Multimedia Appendixes

CBT and BCT coding descriptive data.

URL: <http://asset.jmir.pub/assets/d44b7c56b96ac0ed2d9931acfb0a40db.xlsx>

