Just-in-time Adaptive Interventions for Mental Health: A Scoping Review

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17 March, 2025

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Abstract

Background: Given the high prevalence of mental disorders, the shortage of psychotherapy places, and the lack of personalization in mobile mental health, Just-in-time adaptive interventions provide a promising new solution for mental disorders. As this field of research is still evolving, few research papers on JITAIs for mental health exist. This scoping review provides an overview of the study, sample and intervention characteristics, adherence, effectiveness, and decision elements of available literature on JITAIs for mental health. **Method:** The databases PsycINFO, PubMed, and Web of Science were searched, on September 13th, 2024. Studies that tailor their content to the users' changing internal state and/or context or to states of vulnerability/opportunity and receptivity, focused on mental health, integrated technology within their intervention, and had a quantitative study design were included. A narrative synthesis was conducted to summarize and synthesize the findings. **Results:** Thirteen studies with 1736 participants were included. The studies' targets of intervention included: anxiety, depression, stress, rumination, symptoms of schizophrenia, well-being, sleep, and bipolar disorder. RCT was the primary study design used by the included studies. Cognitive behavioral therapy was the most frequently used therapeutic approach. The review identified high completion rates (M = 81%), moderate user engagement (M = 54%), moderate dropout rates (M = 22%), and statistically significant effects on several mental health outcomes of JITAIs for mental health for the included studies. **Discussion:** JITAIs for mental health show promising potential as a treatment measure for mental disorders. However, detailed research on different treatment approaches, the long-term effects, and effective decision elements of JITAIs for mental health is highly needed for them to become a sustainable solution to current problems.

Keywords: Just-in-time adaptive interventions, JITAIs, mental health

Mental health has gained more attention in recent years. Nowadays, a wide range of mental health support services exist and continue to grow. However, despite these resources, the prevalence of mental disorders continues to rise globally. Approximately one in four people suffer from a diagnosable mental disorder in a given year (Johns Hopkins Medicine, n.d.). Similarly, data from the World Health Organization (2019) showed that 970 million people are affected worldwide. Mental disorders can encompass a wide variety of conditions

such as depression, anxiety, bipolar disorders, post-traumatic stress disorders, and psychotic disorders. Mental disorders often result in significant stress levels, risk of self-harm, and substantial impairment in social and occupational functioning, often across an individual´s lifespan (Schäfer et al., 2016). Mental disorders produce a significant societal burden, with some researchers claiming that it is the highest-ranking cause of incapacity to work (Harvey et al., 2009). In 2021 alone, mental disorders led to 700,000 deaths by suicide (World Health Organization, 2021). Concluding, these disorders do not only strain the affected individuals, but also healthcare systems, economies, and social relations, emphasizing the urgent need for further mental health support and interventions.

Treatment

Psychotherapy is a well-researched option for the treatment of mental disorders. Meta-analyses highlighted the effectiveness of psychotherapy across a wide range of mental disorders (Cuijpers et al., 2024; Dragioti et al., 2017; Kindred et al., 2022). Within psychotherapy, different evidence-based treatment approaches exist such as cognitive behavioral therapy (CBT), which is one of the most extensively researched approaches (Fordham et al., 2021; Kindred et al., 2022). Besides CBT, a range of other treatment approaches exist that have proven to be effective such as problem-solving therapy (Bell & D'Zurilla, 2009), interpersonal therapy (Cuijpers et al., 2016), acceptance and commitment therapy (Gloster et al., 2020), positive psychological approaches (Carr et al., 2020), behavioral approaches (Hagger & Weed, 2019), and mindfulness-based treatment approaches (Spijkerman et al., 2016). It seems apparent that a wide range of different treatment approaches exist within psychotherapy that have been extensively studied and are recognized for their effectiveness in treating various mental disorders.

Yet despite the existence of several treatment approaches, several barriers still hinder the widespread implementation of these therapies. Psychotherapy remains costly (Zhu et al., 2024), and access is limited by a shortage of trained clinicians, long waiting lists, and few therapy slots (Punton et al., 2022; Schaffler et al., 2022; World Health Organization, 2022). As psychotherapy is traditionally administered face-to-face, geographic constraints restrict access, particularly in rural areas. However, mobile mental health interventions show a lot of promise in tackling these issues. Mobile mental health interventions use mobile devices like smartphones or laptops to provide mental health support, even in rural areas (Becker, 2016). Although mobile mental health interventions increase the accessibility of treatment approaches, they often lack personalization, which research shows to be crucial for enhancing treatment efficacy (Li et al., 2024). Based on the aforementioned limitations of traditional

psychotherapy and mobile mental health interventions, there is a demand for an intervention that offers enhanced accessibility and tailored care. One solution to overcome these disadvantages might be the just-in-time adaptive intervention (JITAI). JITAIs use technology to tailor support, while considering the individuals' needs in real-time (Nahum-Shani et al., 2018).

Just-in-time Adaptive Intervention

In the literature, different terms have been used to describe JITAIs, such as dynamic tailoring, intelligent real-time therapy, context-aware interventions, and ecological momentary intervention (EMI) (Hardeman et al., 2019; Lu et al., 2022). This review uses the term JITAI throughout this paper. An intervention qualifies as a JITAI when it aims to adapt the support provided to an "individual's changing internal and contextual state" and aims to provide support "at the moment and in the context that the person needs it most and is most likely to be receptive" (Nahum-Shani et al., 2018, p.446). To determine the appropriate moment for an intervention, JITAIs try to identify a user´s state of vulnerability/opportunity and receptivity. A state of vulnerability/opportunity is defined as "a period of susceptibility to negative health outcomes (vulnerability) or to positive health behavior changes (opportunity)" (Nahum-Shani et al., 2018, p.448). Receptivity "is defined as the individual's transient ability and/or willingness to receive, process, and utilize just-in-time support" (Nahum-Shani et al., 2018, p.450). Because JITAIs identify states of vulnerability/opportunity and receptivity, they have the capacity to include a high degree of personalization (Bell et al., 2023; Teepe et al., 2021). Considering that states of vulnerability/opportunity and receptivity are highly dynamic (Nahum-Shani et al., 2018), traditional face-to-face sessions or static mobile mental health interventions, often fail to capture them. JITAIs, on the other hand, enable real-time mental health data collection, through the use of technological devices like smartphones or wearables, and tools like GPS or ecological momentary assessments (EMA). EMAs are in-the-moment self-reports, providing insights into an individual's state during real-time (Doherty et al., 2020). Through devices and tools, JITAIs gather data that is needed to determine the optimal time and content for an intervention delivery (Hardeman et al., 2019).

The gathered data is then used by decision points, tailoring variables, intervention options, and decision rules to determine states of vulnerability/opportunity and receptivity for the delivery of an intervention. For this review, these terms fall under the name decision elements. The decision points are "points in time at which an intervention decision must be made." The tailoring variable provides "information concerning the individual that is used for

individualization (i.e., to decide when and/or how to intervene).” Intervention options are an “array of possible treatment/actions that might be employed at any given decision point” (Nahum-Shani et al., 2018, p.448). The decision rules “operationalize the adaptation by specifying which intervention option to offer, for whom, and when. In other words, the decision rules link the intervention options and tailoring variables” (Nahum-Shani et al., 2018, p.452). Decision rules can be differentiated between static and adaptive decision rules. Static decision rules refer to time-irrelevant, pre-specified interventions, while adaptive decision rules are based on real-time data, allowing for dynamic adjustments to the intervention (Perski et al., 2022). Together, these decision elements enable JITAIs to deliver personalized and context-sensitive interventions to dynamically respond to individuals´ needs in ways traditional interventions and mobile mental health interventions cannot.

Available Research on JITAIs

Available research on JITAIs highlights that this field is still evolving (Guan et al., 2024). Nevertheless, research exists providing insights into JITAI's effectiveness. For instance, Wang and Miller´s (2020) meta-analytical review mainly including general health outcomes (e.g., weight loss, physical activity, smoking cessation) showed that JITAIs are effective compared to waitlist control groups and active control groups, with effects remaining stable across treatment duration, participants´ age, and targeted behavior. Additionally, evidence from randomized controlled trials demonstrated that JITAIs for mental health are effective interventions in reducing symptoms of depression, anxiety, stress, and ruminative thoughts compared to control groups (Bell et al., 2023; Proudfoot et al., 2013). Although evidence exists of JITAIs´ effectiveness for general health and mental health, research also underlines the importance of adherence when examining the effectiveness of an intervention. Even when interventions have proven to be effective, nonadherence to an intervention can negatively impact treatment success (Jakob et al., 2022). Previous research on interventions using technology has revealed variation in the reporting of adherence (Donkin et al., 2011). Therefore, this review defines adherence as the extent to which participants follow the interventions they are given (Bissonnette, 2008). To conclude, when reviewing effectiveness, adherence needs to be among the researched factors to truly understand the potential treatment success of JITAIs.

Besides providing insights into JITAIs´ effectiveness and adherence, available reviews on JITAIs have introduced a reporting checklist to improve the transparency of reporting (Hsu et al., 2024) and examined the degree of automation of JITAIs (Oikonomidi et al., 2023). Other reviews have provided an overview of key JITAI characteristics such as

study, sample, and intervention characteristics, as well as reports on adherence, effectiveness, decision elements, feasibility, and acceptability (Hardeman et al., 2019; Perski et al., 2022). However, the included research papers in these reviews largely focus on general health outcomes instead of mental health. None of these reviews, solely reviewed JITAIs for mental health. The limited reviews available that focus on JITAIs for mental health, found modest but significant effects of their interventions and highlight the need for further investigation of this field (Lu et al., 2022). Additionally, Teepe et al.´s (2021) review found that from 28 apps that are currently available to download for depression only a minority utilizes the data gathered from the participants to tailor their content to the individual. Thus, not leveraging the potential of JITAIs. These findings indicate that while some research on JITAIs for mental health exists, knowledge of key characteristics of JITAIs for mental health is limited and that a general overview of these characteristics remains absent.

Current study

Considering that mental disorders remain prevalent and JITAIs hold the potential to overcome barriers in traditional and mobile mental health interventions such as limited access, and lack of personalization, JITAIs warrant further academic research. At the same time, scientific literature on JITAIs remains limited to date, particularly regarding JITAIs for mental health. Therefore, this scoping review aims to review available JITAI research for mental health with quantitative study designs to provide a previously missing overview and highlight research gaps to guide future JITAI research. Hence, this scoping review investigates the following research questions:

1. What are the study and sample characteristics of JITAIs for mental health?
2. What intervention characteristics have been used in JITAIs for mental health?
3. What is the current evidence regarding adherence and effectiveness of JITAIs for mental health?
4. What decision elements are used in JITAIs for mental health?

Method

Research Design

The current study employs the research design of a scoping review as it is the best method to answer the above-mentioned research questions. A scoping review aims to explore the breadth of the literature, summarize the evidence, inform future research, and address knowledge gaps (Peters et al., 2020). As the field of JITAIs for mental health is still new and has been little explored, the scoping review's explorative and descriptive nature fits the

broader research questions (Peters et al., 2020). To ensure quality and transparency, the current study followed the PRISMA extension checklist for reporting scoping reviews (Tricco et al., 2018).

Eligibility Criteria

The author took an inclusive approach. Studies were included when the intervention had tailored its content to the users' changing internal state and/or context or to states of vulnerability/opportunity and receptivity. Moreover, studies were included that targeted mental health, integrated technology within the intervention, used validated instruments, and included information on adherence or intervention effectiveness. The papers had to be reported in English. Qualitative studies, review papers, conference proceedings, abstract dissertations, study protocols, and not-peer-reviewed papers were excluded, to focus on primary research with quantitative study designs to ensure the quality of the papers.

Table 1

Eligibility Criteria.

Inclusion	Exclusion
Intervention must tailor its content to the users' changing internal state and/or context or to states of vulnerability/opportunity and receptivity	Not peer-reviewed (e.g. preprints)
Intervention must target mental health (e.g. depression, anxiety)	Interventions not targeting mental health (e.g. diet, weight loss)
Technology-based mental health interventions	Conference proceedings, abstracts, dissertations, study protocols
At least one validated instrument assessing a mental health-related outcome	Qualitative studies and review papers
Written in the English language	
Studies have to report adherence (e.g. dropout rate, completion rate, user engagement) or intervention effectiveness (e.g. symptom reduction, quality of life)	
Quantitative study designs (RCT, MRT, quasi-experiment)	

Information sources

As recommended by Sutton et al. (2019), a bibliographic database search was conducted, and grey literature was not included due to contradicting guidelines. PsycINFO, PubMed, and Web of Science were searched on September 13th, 2024. All articles published until then were initially included. On October 17th, 2024, a reference list search was conducted to expand the number of studies of the final data set. Three recent review papers were cross-checked: Lu et al. (2022), Oikonomidi et al. (2023), and Wang and Miller (2020).

Search Strategy

An electronic search was conducted. A combination of search terms related to JITAI, and mental health were used. JITAI-related terms included terms such as just-in-time adaptive intervention, ecological-momentary intervention, and context-aware intervention. Mental health-related terms included terms such as anxiety, depression, psychosis, and mental health. Asterisks were used for certain terms to broaden the search, e.g., depress∗. Booleans AND and OR were used to narrow down the search to the field of interest. The search terms were applied to the titles, abstracts, and keywords. The final search string for all databases can be found in Appendix I.

Selection and Data Collection Process

Articles identified through the electronic and bibliographic database search were exported into Covidence and any duplicate records were automatically removed. The author of this paper independently conducted the title, abstract, and full-text screening with the pre-specified in-, and exclusion criteria specified above. Data was extracted using a self-generated Microsoft Excel extraction form, inspired by the JBI data extraction tool and Cochrane data extraction template (Higgins et al., 2024; Peters et al., 2020). The author independently extracted the data. The extraction form including all data items with their definition can be found in Appendix II.

Data Items

To answer the research questions, several data items were extracted. For the study characteristics, details were extracted on the first author´s name, publication year, country, study design (e.g., randomized controlled trial (RCT), population (e.g., university students), the target of intervention(e.g. depression), meaning the type of condition targeted by the intervention, clinical level (nonclinical, subclinical, clinical), which indicates whether participants were psychologically screened by a clinician or the authors before the study, control group (e.g. waitlist control), and comorbidity. Sample characteristics included data on

the mean age of the participants, the percentage of female participants, and the total sample size. Intervention characteristics comprised the treatment approach (e.g., CBT, ACT), duration of the intervention in weeks, the length of a single intervention in minutes, adjunctive treatment, and type of adjunctive treatment (e.g., CBT for 6 weeks). To gain an understanding of the extent to which participants adhere to the intervention, data on dropout rates, user engagement, and completion rates were extracted. The completion rate is defined as the number of intervention modules completed by the participants (Donkin et al., 2011). It was also noted whether and what type of incentives were used to encourage adherence. For effectiveness, statistically significant and non-significant findings as well as their effect sizes of mental health-related outcome measures (e.g., PHQ-7, and QIDS-C) were extracted. For decision elements, information on decision points, decision rules, tailoring variables, and intervention options was extracted. Furthermore, it was extracted whether an intervention used active (e.g., EMA) or passive measurement (e.g., GPS) (Perski et al., 2022). Additionally, it was identified whether a decision rule was static or adaptive. A quality appraisal was not conducted in this scoping review, as a quality appraisal is not a compulsory aspect of the scoping review methodology, according to the PRISMA guidelines (Tricco et al., 2018).

Synthesis Methods

For this scoping review, a narrative synthesis was conducted to summarize and synthesize the findings across studies. This method was deemed appropriate due to the diversity of study designs and the broad scope of the included studies. A narrative synthesis is suitable for addressing the research questions, as it enables to provide an overview of the existing evidence.

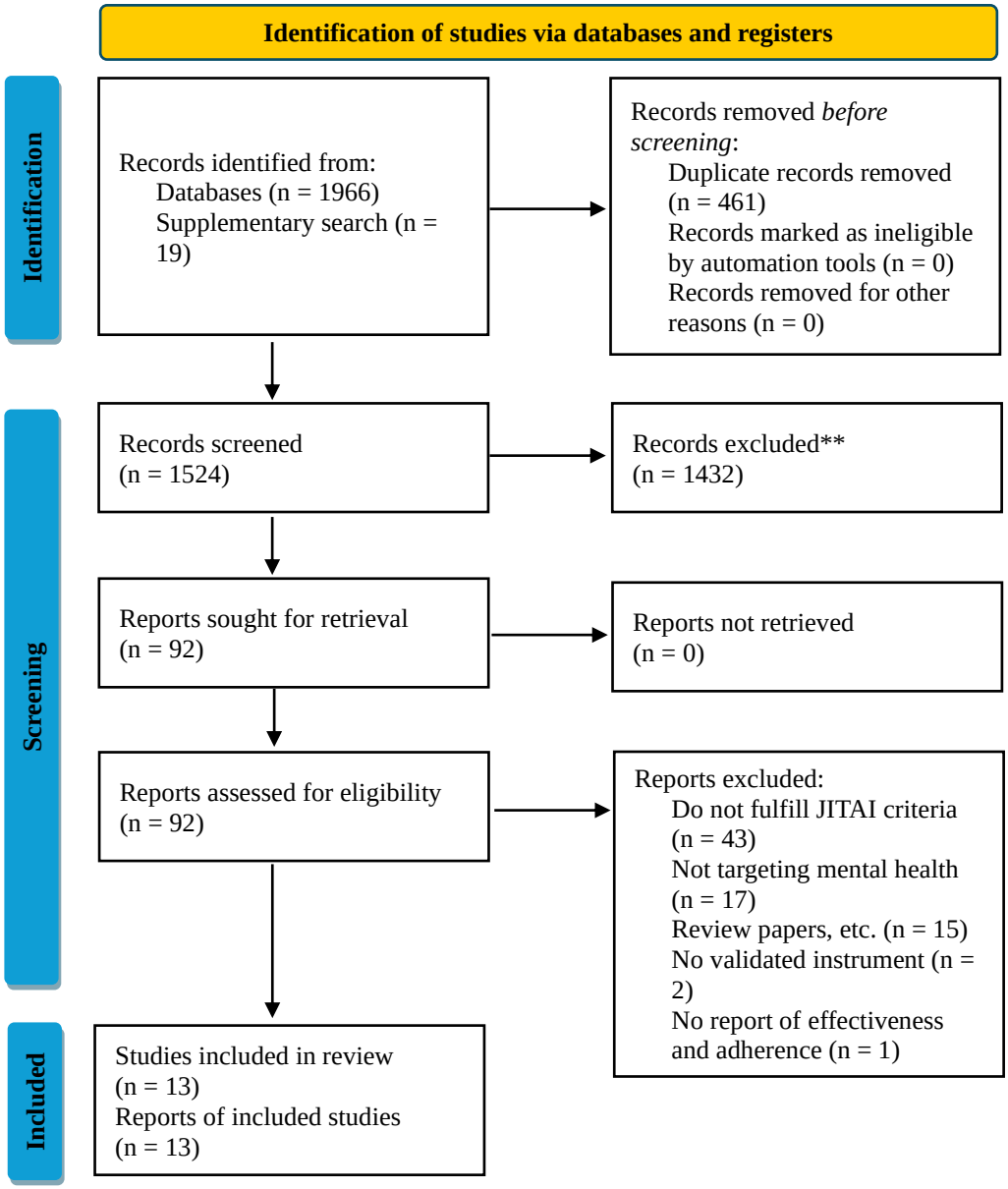
Results

Study Selection

In total, the database search identified 1985 papers. After 461 duplicates had been removed, the abstract screening included 1524. During this stage, 1432 papers were removed, mostly as they did not target mental health and/or JITAIs. During the full-text screening, 72 papers were removed due to not fulfilling the eligibility criteria. Overall, this generated 13 papers to be included in the final dataset.

Table 2

PRISMA flow diagram demonstrating the review process from literature identification to the final dataset (Page et al., 2021).



Sample and Study Characteristics

Across all studies, a total of 1736 participants were included (M = 132), of which 1055 were female. The mean age was 33.53. Looking at the study characteristics, the included studies were conducted in the USA (n = 8), Australia (n = 2), Japan, the Netherlands, and the UK (n = 1). Most studies used a randomized controlled trial (RCT) (n = 5). Others used a pilot RCT, open trial (n = 2), micro randomized trial (MRT), pilot MRT, pilot uncontrolled trial, and single-arm field trial (n = 1). The most frequently targeted populations were patients with a specific mental disorder (n = 6). Others examined the

general population (*n* = 4), university students, sexual assault survivors, and caregivers (*n* = 1). The most common target of intervention was anxiety (*n* = 4). Others targeted depression, stress, rumination (*n* = 2), symptoms of schizophrenia, mental health, well-being, sleep, and bipolar disorder (*n* = 1). Most studies included participants with a clinical diagnosis of the targeted disorder (*n* = 6). Other studies had subclinical (*n* = 2) or nonclinical samples (*n* = 5). Only one paper investigated comorbidities and identified generalized anxiety disorder (GAD) as a comorbidity in their sample (*n* = 1).

Intervention Characteristics

The studies reported using different treatment approaches. The most frequently used treatment approach was CBT (*n* = 8). Additional treatment approaches were behavioral, positive psychology (*n* = 2), ACT, mindfulness, interpersonal psychotherapy, and problem-solving therapy (*n* = 1). Intervention duration ranged between 1 to 12 weeks. The average intervention duration was 6 weeks. The length of a single intervention ranged between 2 - 15 minutes (*n* = 5). Of the studies reporting the usage of adjunctive treatments, all of them used CBT-focused psychotherapy ranging between 4-12 sessions (*n* = 3).

Table 3

Study and sample characteristics.

Authors, Year	Country	Design	Population	Target of intervention	Clinical level	Control group	Comorbidity	Sample size (n)	Mean Age (SD)	Female (n)
Bell et al. (2023)	Australia	Pilot RCT	General population	Repetitive Negative Thinking	Subclinical	Non-treatment control group	No	55	20.6 (2.7)	34
Burns et al. (2011)	USA	Single-arm field trial	MDD patients	Depression	Clinical	No control group	GAD	8	37.4 (12.2)	7
Hanssen et al. (2020)	Netherlands	RCT	Schizophrenia patients	Symptoms of schizophrenia	Clinical	Received the intervention, but no tailoring	No	50	38.5 (9.7)	18
Levin et al. (2019)	USA	RCT	University students	Mental health	Nonclinical	Received the intervention, but no tailoring	No	39	21.85 (5.18)	23
McEwan et al. (2019)	UK	RCT	Sheffield residents	Well-being	Nonclinical	Positive psychological intervention	No	582	28.68 (10.43)	359
Newman et al. (2014)	USA	RCT	GAD patients	GAD	Clinical	TAU	No	34	42.08 (12.5)	20

Proudfoot et al. (2013)	Australia	RCT	General population	Depression, anxiety, stress	Subclinical	Waitlist control group	No	720	38.9 (10.6)	491
Short et al. (2023)	USA	Pilot uncontrolled trial	Sexual assault survivors	Anxiety	Nonclinical	No control group	No	12	25.4 (not reported)	12
Silk et al. (2020)	USA	Open trial	Anxious youth	Anxiety	Clinical	No control group	No	34	11.4 (1.62)	17
Takeuchi et al. (2023)	Japan	MRT	General population	Sleep	Nonclinical	Comparison between feedback days and non-feedback days	No	140	39.15 (10.09)	29
Wang et al. (2023)	USA	Pilot MRT	Caregivers	Stress	Nonclinical	They had access to the intervention but received no reminders	No	36	54.4 (13.05)	28
Wang & Miller (2023)	USA	Pilot RCT	Depression patients	Rumination	Clinical	Non-treatment control group	No	18	Not reported	12
Wenze et al. (2016)	USA	Open trial	Bipolar patients	Bipolar disorder	Clinical	No control group	No	8	44 (11.58)	5

Note. Non-treatment control group = control group did not receive an intervention; TAU = Treatment as usual

Table 4

Intervention characteristics.

Author	Treatment approach	Intervention duration (weeks)	Length of a single intervention (min)	Adjunctive treatment	Type of adjunctive treatment
Bell	CBT & mindfulness	6	2 - 12	No	N/A
Burns	Behavioral activation approach	8	15	No	N/A
Hanssen	Not reported	3	Not reported	No	N/A
Levin	ACT	4	Not reported	No	N/A
McEwan	Positive psychology	1	Not reported	No	N/A
Newman	CBT	12	Not reported	Yes	6-12 sessions of group CBT for GAD
Proudfoot	CBT, interpersonal psychotherapy, problem-solving therapy, & positive psychology	7	10	No	N/A
Short	CBT	2	40-105	No	N/A
Silk	CBT	Not reported	2 - 5	Yes	8 CBT therapy sessions (á one hour) focusing on skill training
Takeuchi	Not reported	2	Not reported	No	N/A
Wang	CBT & behavioral approach	12	Not reported	No	N/A
Wang & Miller	Rumination-focused CBT	5	Not reported	No	N/A
Wenze	CBT	12	2.5	Yes	Psychiatric medication and outpatient care as usual. Approx. one mental health appointment per week

Note. N/A = not available

Adherence and Effectiveness

Six studies provided information on the participant dropout rate, which ranged between 10% and 50% (*M* = 22%), and on the completion rate, which ranged between 58% and 99% (*M* = 81%). Three studies reported participants user engagement, which ranged between 49% and 63% (*M* = 54%). Six studies used incentives ranging between 20-240 of the respective currency. Two studies did not provide any information on adherence measures.

All thirteen studies reported the JITAI effectiveness. The included studies mainly demonstrated statistically significant improvements in primary mental health outcomes such as depression, anxiety, rumination, well-being, psychotic symptoms, post-traumatic stress symptoms (PTSD), sleep quality, and stress (*n* = 11). Secondary significant mental health outcomes were decreased loneliness, avoidance, quality of life, and work and social functioning. The effect sizes ranged from small (*d* = 0.11) to large (*d* = 2.5). Two studies did not find significant effectiveness for their JITAIs. However, their JITAI groups had a better symptom reduction compared to the control groups receiving treatment as usual (TAU) (McEwan et al., 2019; Wenze et al., 2016). The results of the included studies with a more rigorous methodology such as RCT study designs, had significant improvements in symptoms of depression, anxiety, stress, and symptoms of schizophrenia for the JITAI groups compared to the control groups. The effect sizes ranged from small (*d* = 0.11) to medium (*d* = 0.55) (Hanssen et al., 2020; Proudfoot et al., 2013). Studies with less methodological merit such as open-trial designs revealed mixed findings. One of these studies had significant improvements in anxiety sensitivity and PTSD with large effect sizes (*g* = 0.74; *g* = 1.2) (Silk et al., 2020).

Follow-up assessments revealed mixed findings regarding the long-term effects of the results. Proudfoot et al. (2013) maintained near-normal symptom levels three months post-intervention. McEwan et al. (2019) sustained improvements in well-being at one-month follow-up. Silk et al. (2020) did sustain 86% symptom reduction, however, skill acquisition was not sustained at the two-month follow-up. On average the follow-ups were conducted two months post-intervention (*n* = 3). The majority did not conduct a follow-up assessment (*n* = 7).

Decision Elements

The decision elements of JITAIs for mental health vary significantly in terms of intervention options, tailoring variables, and decision rules. For a complete overview of the extracted information on decision elements, refer to Table 6. Most decision rules were static

(*n* = 8), while one study used adaptive rules and another combined static and adaptive rules. Active measurement was the predominant method for determining whether and what type of support to provide (*n* = 8), followed by a combination of active and passive measurements (*n* = 4). Passive measurement was used once. Decision points most frequently occurred after EMAs (*n* = 8), while one study triggered the decision point via GPS detection of green spaces, and another used individually programmed decision points. Some studies did not provide information on the tailoring variables (*n* = 4) and the decision rules (*n* = 3).

Table 5

Decision elements.

Author	Active and/or passive measurement	Decision points	Intervention options	Tailoring variables	Decision rules	Static and/or adaptive decision rules
Bell	Active	After an EMA	12 CBT exercises: breathing exercises, grounding 5 senses, defusion exercise, behavior experiment, problem-solving, experience rating, cognitive reappraisal, social skills training, emotional expression, gratitude, three good things, self-compassion	Not reported	Based on the RNT score, mood, location, and activity level the JITAI recommends 1 out of 12 exercises	Static
Burns	Both	After an EMA	9 lessons on a website about e.g. self-monitoring, goal setting, behavior experiment, exposure, recognizing and changing avoidance patterns, psychoeducation, pleasurable experiences	Based on the EMA and the data gathered from the sensors the JITAI determines the participant's mood. When the mood was outside the typical range, a message was sent suggesting the use of an intervention	Based on the predicted mood, one of the 9 lessons is provided.	Both

Hanssen	Active	Not reported	Personalized feedback in one of the following categories: psychotic symptoms, social engagement, health behavior, physical activity, mood, and emotion	Not reported	Personalized feedback from one out of six categories was provided to the user based on their responses to the EMA.	Static
Levin	Active	After an EMA	4 ACT components. Each ACT component included 28 quick skills and 6 depth skills such as defusion exercises, exercises on acceptance, values, and being in the present moment	The JITAI calculated the highest-rated score of the EMA, which focused on depression, anxiety, valued action, avoidance, cognitive fusion, inattention to the present, and lack of values connection then recommended an ACT intervention	Participants were assigned to one of four ACT components based on the highest-rated score of the EMA. When the highest-rated score was avoidance, then acceptance skills. When cognitive fusion, then cognitive defusion. When inattention to the present then present moment. When lack of values connection then values	Static
McEwan	Passive	When the GPS noticed that the participant was in a green space	Write down one good thing that you have noticed	When the JITAI notices the user is in a green space then the intervention is triggered	If the participant is in a green space they are asked to write down one good thing they have noticed	Adaptive

Newman	Active	After an EMA	Relaxation module (6x PMR, mind-body scan, diaphragmatic breathing, pleasant imagery) and cognitive restructuring	The JITAI calculated the user´s anxiety score between 0-10. Depending on whether the score was above or below 3 the required intervention was triggered.	If the anxiety score of a participant was a 3 or lower) the user received words of encouragement. If the score was above 3 they were invited to implement an intervention option	Static
Proudfoot	Active	After an EMA	12 skill-building modules, e.g. problem-solving,	An intervention was triggered when the three highest-rated symptoms were determined	Based on the three highest-rated symptoms the JITAI generated personalized feedback including skill-building modules fitting the highest-rated symptoms	Static
Short	Active	After an EMA	The feedback e.g. reminded participants that reexperiencing is normal for PTSD, advised them to let these memories pass, and provided links to helpful material	An intervention was triggered after the levels of PTSD symptoms were scored	Depending on the levels and symptoms of PTSD the participant received personalized feedback.	Static
Silk	Both	Individually preprogrammed	4 interactive mini-games, focusing on problem-solving, recognizing and changing avoidance patterns, cognitive reappraisal, emotion identification	An intervention was initiated either during pre-entered times or at the recognition of certain locations	Not reported	Not reported

Takeuchi	Both	Not reported	Personalized feedback messages and sleep hygiene guidelines	Personalized sleep feedback was sent to the participants depending on the calculated relative sleep sufficiency score of the previous night	If the sleep hours were relatively long for the user´s average, they received negative feedback. If the sleep hours were relatively short, they received alerting feedback	Static
Wang	Both	Not reported	Personalized messages summarizing personal data and encouraging behavior change	Not reported	Not reported	Not reported
Wang & Miller	Active	After an EMA	Feedback tailored to the trigger and training materials, focusing on problem-solving and emotion regulation	An intervention was prompted when the user felt triggered to engage in ruminative episodes, and a state of vulnerability and receptivity was detected through a daily activity survey	When the user felt triggered to engage in ruminative episodes, they received feedback and/or training materials tailored to the trigger	Static
Wenze	Active	After an EMA	Semi-individualized feedback messages on mood or symptoms using psychoeducation	Not reported	Not reported	Not reported
Wenze	Active	After an EMA	Semi-individualized feedback messages on mood or symptoms using psychoeducation	Not reported	Not reported	Not reported

Note. RNT = Repetitive negative thinking; PMR = Progressive Muscle Relaxation

Discussion

This scoping review aimed to provide a previously missing overview of JITAIs for mental health with quantitative study designs to guide future research. To do so, this scoping review identified, and summarized the study, sample, and intervention characteristics, adherence, effectiveness, and decision elements. The results identified RCTs as the primary study design and CBT emerged as the most frequently used treatment approach. JITAIs for mental health demonstrated high completion rates, moderate user engagement, and moderate dropout rates. Most of the included studies reported statistically significant improvements in mental health outcomes. The results for the decision elements lacked coherent reporting, especially for the intervention options, tailoring variables, and decision rules. The majority of the JITAIs for mental health used active instead of passive measurements.

The review revealed heterogeneity across the included studies. Heterogeneity was evident for the target of intervention, which ranged from anxiety, depression, stress, rumination, symptoms of schizophrenia, mental health, well-being, sleep to bipolar disorder. Looking at other reviews, heterogeneity of targets of intervention seems to be a common theme, as several reviews even mixed general health and mental health when investigating JITAIs (Hsu et al., 2024; Oikonomidi et al., 2023). A reason for this could be the limited literature in this field and the advantage of providing a more concise overview when different JITAI studies are included. Furthermore, the results mainly identified studies with RCT study designs. Including research with RCT study designs seems to be common within JITAI reviews (Hsu et al., 2024; Perski et al., 2022). This may be attributed to RCTs' ability to provide high-quality research (Stanley, 2007). By incorporating randomization, RCTs minimize biases and investigate cause-effect relationships rigorously (Hariton & Locascio, 2018). Even though heterogeneity exists between the targets of intervention, the review also identified the high-quality study design of RCTs to be the primary method for JITAIs for mental health for this review.

Looking at the intervention characteristics, CBT emerged as the most frequently used treatment approach in JITAIs for mental health. This finding aligns with previous research on JITAIs for mental health, which also favors this treatment approach (Lu et al., 2022). The reason for this preference might be that CBT is one of the most researched treatment approaches and has proven to be effective for general health, as well as mental health (Fordham et al., 2021; Hedman et al., 2012). Nevertheless, in psychotherapeutic practice, it is not new that the one-size-fits-all method is proven to be less effective than personalizing the intervention to the individual (Li et al., 2024; Nye et al., 2023). Furthermore, other treatment

approaches like ACT, positive psychology, mindfulness-based therapy, interpersonal psychotherapy, and problem-solving therapy have been proven to be effective for mental disorders and have been used by JITAIs (Bell & D'Zurilla, 2009; Carr et al., 2020; Cuijpers et al., 2016; Gloster et al., 2020; Levin et al., 2019; Proudfoot et al., 2013; Spijkerman et al., 2016). By incorporating these various treatment approaches, JITAIs can be further personalized to match users´ individual needs, symptoms, and preferences. For example, users who struggle with identifying and prioritizing their values might benefit from JITAIs providing ACT, which helps users move toward their values with actions (Levin et al., 2019). Whereas individuals experiencing conflicts that create stress could receive problem-solving therapy (Proudfoot et al., 2013). Although some JITAIs already used other treatment approaches besides CBT (Burns et al., 2011; Levin et al., 2019; Proudfoot et al., 2013), they are not widely implemented and even fewer JITAIs incorporate intervention options from different treatment approaches. Therefore, further research on JITAIs with other treatment approaches than CBT is necessary to advance personalization. Additionally, to be able to tailor different treatment approaches to the individual effectively, research on which treatment approaches work best for whom and in what context is needed for JITAIs for mental health. To be able to efficiently investigate this, it is advised to use a micro-randomized controlled trial (MRT) design, as this design is the superior design to investigate whether an intervention has the intended effects, for whom they are effective, and what factors moderate these effects within JITAI research (Klasnja et al., 2015).

Regarding adherence, JITAIs for mental health demonstrated high completion rates, moderate dropout rates, and moderate user engagement. Considering that mobile mental health is usually characterized by moderate completion rates, high dropout rates, and low user engagement, the findings of the current review are considered to be better than many findings within this field (Berry et al., 2016; Dowling et al., 2023). Although the current findings are better than others, dropout rates and user engagement were still only moderate. The included studies did not discuss factors that could have influenced the dropout rate or user engagement. However, other studies provide insights into possible influential factors. Factors that could have an impact are non-existent user-friendliness, lack of a user-centric design, meaning that the intervention does not meet the needs of the user, and privacy concerns (Torous et al., 2018). Additionally, within JITAIs active measurements which require more time and effort could burden user participation more compared to passive measurements, which require less time and effort from the user (Xu & Smit, 2023). It seems apparent that many factors exist that can impact dropout rates and user engagement negatively and that

research investigating the impact of these factors on JITAIs for mental health is missing. Therefore, future experimental studies investigating factors that influence dropout rates and user engagement of JITAIs for mental health are warranted to be able to improve JITAI designs and eventually reduce dropout rates and increase user engagement.

In terms of effectiveness, the majority of the studies reported statistically significant improvements in mental health outcomes. This aligns with previous findings on the effectiveness of health-related JITAIs (Wang & Miller, 2020; Xu & Smit, 2023). While the findings of this review highlight significant short-term improvements in mental health outcomes, it was noticed that the long-term effects between the included studies were mixed. Different reasons could explain these mixed findings of the long-term effects. Firstly, there was heterogeneity between the populations and the JITAI designs. This could have meant that different populations benefitted from JITAIs for different durations or that different JITAI designs provided enhanced long-term effects compared to other designs. Another reason could be that JITAIs aim to provide support during states of vulnerability/opportunity and receptivity. Although immediate support in such moments can generate momentary improvement, the question arises as to whether these immediate support interventions that JITAIs are currently providing, can foster learning experiences that create a sustained change of maladaptive thoughts and behaviors in the long run. Therefore, to answer whether JITAIs for mental health have the potential to not just provide immediate support but also facilitate sustained change, the long-term effectiveness of the intervention should be investigated through experimental studies for longer periods than 2 months.

Looking at the decision elements, the lack of coherent reporting was notable. This was especially visible in the intervention options, tailoring variables, and decision rules. Information on these elements was either little reported or not provided at all. The authors did not explain the reason behind their broad reporting. This finding aligns with other general health and mental health reviews on JITAIs, which highlighted missing or incomplete reporting of information within available JITAI literature (Lu et al., 2022; Oikonomidi et al., 2023; Teepe et al., 2021). Oikonomidi et al. (2023) review found that 43% of the decision rules were not replicable due to incomplete reporting. Since the lack of coherent reporting is a reoccurring issue within research, Hsu et al. (2024) review compared available JITAI research against their reporting checklist. Contrasting to other reviews, this review declared that the majority of the included papers provided sufficient details on their JITAIs. Nevertheless, the review also found that it was unable to identify clear details on intervention options, tailoring variables, and decision rules with the information provided through the

research papers. It seems apparent that especially information on the intervention options, tailoring variables, and decision rules seem to lack reporting completeness in the current JITAI literature. Therefore, to ensure sufficient reporting of decision elements, future research should stick to a reporting checklist such as the one from Hsu et al. (2024). Furthermore, reviews are needed that contact the authors of JITAI research papers to gather the missing information and provide a coherent summary of the decision elements.

The majority of the JITAIs for mental health used active instead of passive measurements like EMAs to collect data that is used to tailor the contents of the intervention. This finding complies with other health-related JITAI studies (Hsu et al., 2024; Oikonomidi et al., 2023; Perski et al., 2022). Active measurements have the advantage that participants consciously provide information about their situation. This can foster awareness and enhance reflection about internal states in certain contexts (Naugthon et al., 2016; Perski et al., 2022). However, active measurements can be burdensome for the user and can be affected by recall biases (Hsu et al., 2024). Biases could lead to the unintentional provision of incorrect information by the user. On the other hand, passive measurements have the advantage of collecting data during real-life situations of the user without needing to ask them and without interfering with their daily activities. Although this would counteract the disadvantages of active measurements, certain ethical considerations have to be taken into account. Passive measurements can lead to data collection of information the user did not intend to share (Maher et al., 2019). Furthermore, it can elicit feelings of discomfort or being tracked (Maher et al., 2019). Given the potential advantages of passive measurements and the fact that active measurements are currently the predominant measurement method for JITAIs, there is a need for further exploration of passive measurements. Future experimental studies should investigate the effects of different passive measurements on the effectiveness and adherence of JITAIs while considering ethical matters.

Strengths and Limitations

One of this scoping review's strengths is its adherence to the PRISMA extension checklist for reporting scoping reviews, which ensured the transparency and quality of this review (Tricco et al., 2018). Another strength of this review is the inclusion of the Nahum-Shani et al. (2018) JITAI definition in its eligibility criteria, which has also been used by bigger reviews of this field (Hsu et al., 2023; Perski et al., 2022; Teepe et al., 2021). This way, this review ensured a consistent understanding of the JITAI term and enabled comparison of JITAIs fulfilling the same core criteria. Even though including a JITAI definition in the eligibility criteria, can be viewed as a strength, the specificity of including a

definition in the eligibility criteria can also be seen as a limitation. This way, JITAI studies that would fulfill different JITAI definitions were potentially excluded. The inclusion of those studies could have created a bigger dataset and a possibly more coherent overview of certain JITAI characteristics. Another limitation of this review is that subjectivity within the decision processes, such as the screening or extraction process, cannot be ruled out as these processes were carried out by a single author. Therefore, a possibility exists that JITAI studies or relevant information have been missed. Despite these limitations, this scoping review provides a transparent and structured overview of existing JITAI literature for mental health by adhering to PRISMA guidelines.

Conclusion

To conclude, this review provided an overview of the available JITAI literature for mental health with quantitative study designs. The review identified the RCT study design and CBT treatment approach to be used the most frequently for JITAIs for mental health. The review found high completion rates, moderate user engagement, moderate dropout rates, and statistically significant effects on several mental health outcomes of JITAIs for mental health. Although these findings show promising potential for JITAIs as a treatment option for mental health, detailed research on different treatment approaches, the long-term effects, and effective decision elements of JITAIs for mental health are highly needed for them to become a sustainable solution to current problems in the mental health care system.

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Appendix I

PsycINFO

(TI("just-in-time adaptive intervention" OR “JITAI” OR “just-in-time adaptive”) OR AB("just-in-time adaptive intervention" OR “JITAI” OR “just-in-time adaptive”) OR KW ("just-in-time adaptive intervention" OR “JITAI” OR “just-in-time adaptive” OR TI("ecological momentary intervention" OR “emi”) OR AB("ecological momentary intervention" OR “emi”) OR KW("ecological momentary intervention" OR “emi”) OR TI(“dynamic tailoring”) OR AB(“dynamic tailoring”) OR KW(“dynamic tailoring”) OR TI(“intelligent real-time therapy”) OR AB(“intelligent real-time therapy”) OR KW(“intelligent real-time therapy”) OR TI(“context-aware interventions”) OR AB(“context-aware interventions”) OR KW(“context-aware interventions”))

AND

(TI("anxiety disorders" OR "anxiety" OR "anxiety symptoms" OR "mental health" OR "mental illness*" OR "depress*" OR "affective disorder*" OR "bipolar" OR "mood disorder*" OR "depression" OR "depressive disorder" OR "depressive symptoms" OR "major depressive disorder” OR "psychosis" OR "psychotic" OR "schizophre*" OR "well-being" OR "wellbeing" OR "quality of life" OR "self-harm" OR "self-injury" OR "stress*" OR "distress*" OR "mood" OR "body image" OR "eating disorder*" OR "sleep*" OR "insomnia" OR "pain" OR "fatigue" OR "psychosomatic" OR “emotion regulation”) OR AB("anxiety disorders" OR "anxiety" OR "anxiety symptoms" OR "mental health" OR "mental illness*" OR "depress*" OR "affective disorder*" OR "bipolar" OR "mood disorder*" OR "depression" OR "depressive disorder" OR "depressive symptoms" OR "major depressive disorder” OR "psychosis" OR "psychotic" OR "schizophre*" OR "well-being" OR "wellbeing" OR "quality of life" OR "self-harm" OR "self-injury" OR "stress*" OR "distress*" OR "mood" OR "body image" OR "eating disorder*" OR "sleep*" OR "insomnia" OR "pain" OR "fatigue" OR "psychosomatic" OR “emotion regulation”) OR KW("anxiety disorders" OR "anxiety" OR "anxiety symptoms" OR "mental health" OR "mental illness*" OR "depress*" OR "affective disorder*" OR "bipolar" OR "mood disorder*" OR "depression" OR "depressive disorder" OR "depressive symptoms" OR "major depressive disorder” OR "psychosis" OR "psychotic" OR "schizophre*" OR "well-being" OR "wellbeing" OR "quality of life" OR "self-harm" OR "self-injury" OR "stress*" OR

"distress*" OR "mood" OR "body image" OR "eating disorder*" OR "sleep*" OR "insomnia" OR "pain" OR "fatigue" OR "psychosomatic" OR “emotion regulation”)

PubMed

(("just-in-time adaptive intervention"[Title/Abstract] OR "JITAI"[Title/Abstract] OR "just-in-time adaptive"[Title/Abstract] OR "ecological momentary intervention"[Title/Abstract] OR "emi"[Title/Abstract] OR "dynamic tailoring"[Title/Abstract] OR "intelligent real-time therapy"[Title/Abstract] OR "context-aware interventions"[Title/Abstract]))

AND

(("anxiety disorders"[Title/Abstract] OR "anxiety"[Title/Abstract] OR "anxiety symptoms"[Title/Abstract] OR "mental health"[Title/Abstract] OR "mental illness*"[Title/Abstract] OR "depress*"[Title/Abstract] OR "affective disorder*"[Title/Abstract] OR "bipolar"[Title/Abstract] OR "mood disorder*"[Title/Abstract] OR "depression"[Title/Abstract] OR "depressive disorder"[Title/Abstract] OR "depressive symptoms"[Title/Abstract] OR "major depressive disorder"[Title/Abstract] OR "psychosis"[Title/Abstract] OR "psychotic"[Title/Abstract] OR "schizophre*"[Title/Abstract] OR "well-being"[Title/Abstract] OR "wellbeing"[Title/Abstract] OR "quality of life"[Title/Abstract] OR "self-harm"[Title/Abstract] OR "self-injury"[Title/Abstract] OR "stress*"[Title/Abstract] OR "distress*"[Title/Abstract] OR "mood"[Title/Abstract] OR "body image"[Title/Abstract] OR "eating disorder*"[Title/Abstract] OR "sleep*"[Title/Abstract] OR "insomnia"[Title/Abstract] OR "pain"[Title/Abstract] OR "fatigue"[Title/Abstract] OR "psychosomatic"[Title/Abstract] OR "emotion regulation"[Title/Abstract]))

Web of Science

(TI=("just-in-time adaptive intervention" OR “JITAI” OR “just-in-time adaptive” OR "ecological momentary intervention" OR "emi" OR "dynamic tailoring" OR "intelligent real-time therapy" OR "context-aware interventions") OR AB= ("just-in-time adaptive intervention" OR “JITAI” OR “just-in-time adaptive” OR "ecological momentary intervention" OR "emi" OR "dynamic tailoring" OR "intelligent real-time therapy" OR "context-aware interventions") OR AK= ("just-in-time adaptive intervention" OR “JITAI” OR “just-in-time adaptive” OR "ecological momentary intervention" OR "emi" OR "dynamic tailoring" OR "intelligent real-time therapy" OR "context-aware interventions”))

AND

(TI= ("anxiety disorders" OR "anxiety" OR "anxiety symptoms" OR "mental health" OR "mental illness*" OR "depress*" OR "affective disorder*" OR "bipolar" OR "mood disorder*" OR "depression" OR "depressive disorder" OR "depressive symptoms" OR "major depressive disorder” OR "psychosis" OR "psychotic" OR "schizophre*" OR "well-being" OR "wellbeing" OR "quality of life" OR "self-harm" OR "self-injury" OR "stress*" OR "distress*" OR "mood" OR "body image" OR "eating disorder*" OR "sleep*" OR "insomnia" OR "pain" OR "fatigue" OR "psychosomatic" OR “emotion regulation”) OR AB=("anxiety disorders" OR "anxiety" OR "anxiety symptoms" OR "mental health" OR "mental illness*" OR "depress*" OR "affective disorder*" OR "bipolar" OR "mood disorder*" OR "depression" OR "depressive disorder" OR "depressive symptoms" OR "major depressive disorder” OR "psychosis" OR "psychotic" OR "schizophre*" OR "well-being" OR "wellbeing" OR "quality of life" OR "self-harm" OR "self-injury" OR "stress*" OR "distress*" OR "mood" OR "body image" OR "eating disorder*" OR "sleep*" OR "insomnia" OR "pain" OR "fatigue" OR "psychosomatic" OR “emotion regulation”) OR AK=("anxiety disorders" OR "anxiety" OR "anxiety symptoms" OR "mental health" OR "mental illness*" OR "depress*" OR "affective disorder*" OR "bipolar" OR "mood disorder*" OR "depression" OR "depressive disorder" OR "depressive symptoms" OR "major depressive disorder” OR "psychosis" OR "psychotic" OR "schizophre*" OR "well-being" OR "wellbeing" OR "quality of life" OR "self-harm" OR "self-injury" OR "stress*" OR "distress*" OR "mood" OR "body image" OR "eating disorder*" OR "sleep*" OR "insomnia" OR "pain" OR "fatigue" OR "psychosomatic" OR “emotion regulation”))

Appendix II

Table 6

Data items of the extraction form.

Study characteristics	
Author	The first author's name
Publication year	Year of publication
Country	The country the study was conducted in
Study design	Type of study design (e.g. randomized controlled trial)
Population	Short description of the sample (e.g. university students)
Target of intervention	Condition targeted by the intervention
Clinical level	Was the sample nonclinical, subclinical, or clinical? Subclinical means that participants were screened for elevated levels of symptoms. Clinical means that the participants were selected after a diagnosis made by a healthcare professional. Nonclinical are participant groups that were not previously screened for existing conditions
Control group	What type of control group (e.g. waitlist control)
Comorbidity	Does comorbidity exist (e.g. depressed patients being treated for cancer)
Sample characteristics	
Mean age	the mean age of the total sample size
Gender	the percentage of female participants
Sample size	The total sample size

Intervention characteristics	
Treatment approach	The psychological theory used within the intervention (e.g. CBT, ACT)
Duration of the intervention	The time from baseline until the end of the intervention in weeks
Length of a single intervention	The time of one intervention session in minutes
Adjunctive treatment	Other treatments that the participants participate in, besides the JITAI intervention (e.g. JITAI and traditional psychotherapy)
Type of adjunctive treatment	The type of adjunctive treatment the patient is receiving (e.g. CBT for 6 weeks)
Treatment approaches	
Treatment approaches	The available treatment content participants work through during intervention sessions (e.g. psychoeducation, goal setting, acceptance exercises)
Adherence	
Dropout rate	The number of participants who dropped out of the study
Completion rate	The number of intervention modules completed by the participants (Donkin et al., 2011)
User Engagement	How much the participants interact with the intervention given in percentage
Incentive	Do the participants receive incentives for participating?
Effectiveness	
Significance	The significant and non-significant results of the outcome measures
Effect sizes	The effect sizes of the significant results
Decision elements	
Decision point	The decision points are “points in time at which an intervention decision must be made” (Nahum-Shani et al., 2018, p.448)

Decision rules	The decision rules "operationalize the adaptation by specifying which intervention option to offer, for whom, and when. In other words, the decision rules link the intervention options and tailoring variables" (Nahum-Shani et al., 2018, p.452)
Static vs adaptive decision rule	Static decision rules refer to time-irrelevant, pre-specified interventions, while adaptive decision rules are based on real-time data, allowing for dynamic adjustments to the intervention (Perski et al., 2022).
Tailoring variable	The tailoring variable provides "information concerning the individual that is used for individualization (i.e., to decide when and/or how to intervene)" (Nahum-Shani et al., 2018, p.448)
Intervention options	Intervention options are an "array of possible treatment/actions that might be employed at any given decision point" (Nahum-Shani et al., 2018, p.448)
Passive or active measurement	Did the intervention use active (e.g. EMA) or passive measurement (e.g. GPS)?