Just-in-time Adaptive Mechanisms of Popular Mobile Applications for Individuals with Depression: Systematic Review

Gisbert Wilhelm Teepe, Ashish Da Fonseca, Birgit Kleim, Nicholas C. Jacobson, Alicia Salamanca Sanabria, Lorainne Tudor Car, Elgar Fleisch, Tobias Kowatsch

Submitted to: Journal of Medical Internet Research on: April 06, 2021

Disclaimer: © The authors. All rights reserved. This is a privileged document currently under peer-review/community review. Authors have provided JMIR Publications with an exclusive license to publish this preprint on it's website for review purposes only. While the final peer-reviewed paper may be licensed under a CC BY license on publication, at this stage authors and publisher expressively prohibit redistribution of this draft paper other than for review purposes.
# Table of Contents

**Original Manuscript**

Supplementary Files

- Fig 1
- Fig 2
- Fig 3
- Fig 4
- Fig 5

Multimedia Appendixes

Multimedia Appendix 1

[unpublished, non-peer-reviewed preprint]
Just-in-time Adaptive Mechanisms of Popular Mobile Applications for Individuals with Depression: Systematic Review

Gisbert Wilhelm Teepe MSc; Ashish Da Fonseca MA; Birgit Kleim Prof Dr; Nicholas C. Jacobson PhD; Alicia Salamanca Sanabria PhD; Lorainne Tudor Car MD; Elgar Fleisch Prof Dr; Tobias Kowatsch PhD

1 Centre for Digital Health Interventions Department of Management, Technology, and Economics ETH Zurich Zurich CH
2 Centre for Digital Health Interventions Institute of Technology Management University of St. Gallen St. Gallen CH
3 Department of Experimental Psychopathology and Psychotherapy University of Zurich Zurich CH
4 Department of Psychiatry, Psychotherapy and Psychosomatics University of Zurich Zurich CH
5 Center for Technology and Behavioral Health Departments of Biomedical Data Science and Psychiatry Geisel School of Medicine, Dartmouth College Hanover US
6 Future Health Technologies Campus for Research Excellence and Technological Enterprise (CREATE) Singapore-ETH Centre Singapore SG
7 Lee Kong Chian School of Medicine Nanyang Technological University Singapore SG
8 Saw Swee Hock School of Public Health National University of Singapore Singapore SG

Abstract

Background: There is an increasing number of smartphone applications (apps) focusing on prevention, treatment, and diagnosis of depression. A promising approach to increase the effectiveness while reducing the individual’s burden is the use of just-in-time adaptive intervention (JITAI) mechanisms.

Objective: With this work, we systematically assess the use of JITAI mechanisms in apps for individuals with depression.

Methods: We systematically searched for apps addressing depression in the Apple App Store, the Google Play Store, and in curated lists from the Anxiety and Depression Association of America, the United Kingdom National Health Service, and the American Psychological Association in August 2020. Relevant apps were ranked according to the number of reviews (Apple App Store) or downloads (Google Play Store). For each app, two authors separately reviewed all publications concerning the app found within scientific databases (PubMed, Cochrane Register of Controlled Trials, PsycINFO, and Google Scholar), publications cited on the app’s website, information on the app’s website, and the app itself.

Results: None of the 28 reviewed apps used JITAI mechanisms to tailor content to situations or individuals. Three apps did not use any measurements, 20 apps exclusively used self-reports that are insufficient to leverage the full potential of JITAI, and the five apps employing self-reports and passive measurements used them as progress or task indicators only. While 23 of the 68 reviewed publications investigated the effectiveness and 14 publications investigated the efficacy of the apps, not one publication mentioned or evaluated JITAI mechanisms.

Conclusions: Promising JITAI mechanisms have not yet been translated into mainstream depression apps. The lack of publications investigating whether JITAI mechanisms lead to an increase of the apps’ effectiveness or efficacy highlights the need for further research, especially in real-world apps.

(JMIR Preprints 06/04/2021:29412)
DOI: https://doi.org/10.2196/preprints.29412

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?
Please make my preprint PDF available to anyone at any time (recommended).
Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain visible.
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in the PubMed Now! service, my accepted manuscript PDF will automatically be made openly available.

Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain visible.
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in the PubMed Now! service, my accepted manuscript PDF will automatically be made openly available.

Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain visible.
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in the PubMed Now! service, my accepted manuscript PDF will automatically be made openly available.
Review

Just-in-time Adaptive Mechanisms of Popular Mobile Applications for Individuals with Depression: Systematic Review

Gisbert W Teepe\textsuperscript{1A}, Ashish Da Fonseca\textsuperscript{2}, Birgit Kleim\textsuperscript{3,4}, Nicholas C Jacobson\textsuperscript{5}, Alicia Salamanca Sanabria\textsuperscript{6}, Lorainne Tudor Car\textsuperscript{7}, Elgar Fleisch\textsuperscript{1,2}, Tobias Kowatsch\textsuperscript{1,2,6,8}

\textsuperscript{A}Corresponding Author

\textsuperscript{1}Centre for Digital Health Interventions, Department of Management, Technology, and Economics, ETH Zurich, Zurich, Weinbergstrasse 56/58, 8092 Switzerland

\textsuperscript{2}Centre for Digital Health Interventions, Institute of Technology Management, University of St. Gallen, St. Gallen, Dufourstrasse 40a, 9000 St. Gallen, Switzerland

\textsuperscript{3}Department of Experimental Psychopathology and Psychotherapy, University of Zurich, Binzmühlestrasse 14, 8050 Zurich, Switzerland

\textsuperscript{4}Department of Psychiatry, Psychotherapy and Psychosomatics, University of Zurich, Zurich, Lenggstrasse 31, 8032, Switzerland

\textsuperscript{5}Center for Technology and Behavioral Health, Departments of Biomedical Data Science and Psychiatry, Geisel School of Medicine, Dartmouth College, Hanover, 46 Centerra Parkway, Lebanon, New Hampshire 03766, United States

\textsuperscript{6}Future Health Technologies, Campus for Research Excellence and Technological Enterprise (CREATE), Singapore-ETH Centre, Singapore, 1 Create Way, 138602, Singapore

\textsuperscript{7}Lee Kong Chian School of Medicine, Nanyang Technological University, Singapore, 11 Mandalay Road, 308232, Singapore

\textsuperscript{8}Saw Swee Hock School of Public Health, National University of Singapore, Singapore, 12 Science Drive 2, 117549, Singapore

https://preprints.jmir.org/preprint/29412 [unpublished, non-peer-reviewed preprint]
Abstract

**Background:** There is an increasing number of smartphone applications (apps) focusing on prevention, treatment, and diagnosis of depression. A promising approach to increase the effectiveness while reducing the individual’s burden is the use of just-in-time adaptive intervention (JITAI) mechanisms.

**Objective:** With this work, we systematically assess the use of JITAI mechanisms in apps for individuals with depression.

**Methods:** We systematically searched for apps addressing depression in the Apple App Store, the Google Play Store, and in curated lists from the Anxiety and Depression Association of America, the United Kingdom National Health Service, and the American Psychological Association in August 2020. Relevant apps were ranked according to the number of reviews (Apple App Store) or downloads (Google Play Store). For each app, two authors separately reviewed all publications concerning the app found within scientific databases (PubMed, Cochrane Register of Controlled Trials, PsycINFO, and Google Scholar), publications cited on the app’s website, information on the app’s website, and the app itself.

**Results:** None of the 28 reviewed apps used JITAI mechanisms to tailor content to situations or individuals. Three apps did not use any measurements, 20 apps exclusively used self-reports that are insufficient to leverage the full potential of JITAI, and the five apps employing self-reports and passive measurements used them as progress or task indicators only. While 23 of the 68 reviewed publications investigated the effectiveness and 14 publications investigated the efficacy of the apps, not one publication mentioned or evaluated JITAI mechanisms.

**Conclusions:** Promising JITAI mechanisms have not yet been translated into mainstream depression apps. The lack of publications investigating whether JITAI mechanisms lead to an increase of the apps’ effectiveness or efficacy highlights the need for further research, especially in real-world apps.

**Keywords:** Depression; Digital Mental Health; Smartphone Applications; Just-in-time Adaptive Interventions; Effectiveness
Introduction

Worldwide each year at least 246 million people suffer from depression [1] and depression is the leading cause for years lived with disability [2]. While effective treatments for depression exist [3-5] most individuals in need still do not receive it[6], or those obtaining treatment do not benefit. People seeking help often face barriers such as high costs for treatment, a shortage of trained clinicians, the stigma associated with seeking help, and accessibility difficulties [7-10].

Mobile applications (apps) may have the potential to address the rising prevalence and insufficient resources available for the treatment of depression [11,12]. Apps are already an integral part of most people's everyday lives [13], and the threshold for engagement with apps is assumed low resulting in prompt, flexible, portable, and anonymous treatment [14]. Individuals otherwise not reachable could receive treatment [15] and interventions could be delivered in economies with limited resources for mental health [16]. Small to large effect sizes are reported by several systematic reviews showing apps and other digital interventions to reduce symptoms of mental health problems including depression [17-20]. Finally, apps can be used in real-life situations, where behavior change is most desirable and clinicians cannot intervene [14].

The aim of this work is to complement the existing assessment of apps addressing depression by focusing on the use of just-in-time adaptive intervention (JITAI) mechanisms [21,22]. JITAIs aim to deliver an adaptive treatment (i.e. personalized/tailored) at a time of vulnerability (i.e. “person’s transient tendency to experience adverse health outcomes or to engage in maladaptive behaviors” (p. 1210) [21]) and receptivity (i.e. “the person’s transient tendency to receive, process, and use the support provided” (p. 1210) [21]). The tailoring of the treatment and timing is to be determined by measuring changes in relevant variables (e.g. changes in mood). While ecological momentary assessments may facilitate the detection of these states of vulnerability and receptivity, passive measurements (e.g. using the location derived from a smartphone’s GPS data) are regarded as the gold standard of measurements for JITAIs. These passive measurements have the advantage of enabling an unobtrusive, continuous observation [23]. JITAIs tailoring the content to the person, situation, and time by using these passive measurements were therefore proposed to reduce the burden and increase the effectiveness of interventions [21, 22].

Evidence for higher effectiveness of JITAIs compared to non-JITAI treatment and waitlist control groups was investigated in a recent meta-analysis [24], finding moderate to large effect sizes (Hedges’ $g = 1.65$ when comparing to waitlist-control and Hedges’ $g = 0.89$ when comparing to non-JITAI treatments) of primary outcomes produced by 33 empirical studies. Due to this potential of JITAIs to increase effectiveness while reducing the burden and the prominence of the JITAI framework in the scientific community, we aim to review to what degree popular apps addressing depression use JITAI mechanisms by reviewing what and how relevant symptoms of depression (e.g. mood) are measured. We are also interested in whether peer-reviewed evidence can be found that investigated increased effectiveness or efficacy of these apps attributable to the usage of JITAI mechanisms.

To this end, we systematically assessed popular apps targeting depression, i.e. apps that are most reviewed on the Apple App Store and most downloaded on the Google Play Store. We
argue that the investigation of JITAI mechanisms is necessary due to their potential of increasing effectiveness while simultaneously decreasing the burden of users. The focus on popular apps is important because they are listed at the top of search results and thus, are very likely to be downloaded and used [25]. Moreover, a high number of downloads implicates that they have been found useful by users [26], and may indicate that people continue to use or recommend them. Recent evidence also indicates that the two most popular apps for depression and anxiety were responsible for 90% of active users [27].

**Methods**

**Search Strategy and Selection Criteria**
We conducted this systematic review following the same methods used in existing reviews of popular apps addressing mental health problems. We systematically identified and reviewed apps that were publicly available in the U.S. and U.K. app stores, because investments in digital health companies in these countries ranked first (US 2019: 7.4 billion USD) and second (UK 2019: 5 billion USD) of all English-speaking countries in 2019 [28]. The Apple App Store and Google Play Store were used as they have a combined market share of ~99.4% [29]. We searched the two stores by entering the term “depression” in the search fields of the respective stores and included all apps found in both stores of both countries. We also reviewed curated lists of health apps from prominent organizations, namely the Anxiety and Depression Association of America [30], the National Health Service [31], and the American Psychological Association [32]. By doing so, we wanted to ensure that we did not miss any app recommended by important institutions and experts for mental health. The apps found on the respective lists addressed several different mental health problems. We selected only the apps addressing depression for further assessment. Searches were carried out in August 2020.

For further assessment, we included apps that (1) targeted the treatment of depression or reduction of symptoms of depression by (2) delivering at least one active ingredient and were (3) available in English. We defined an active ingredient along with previous work from Michie [33], as a function supporting the users in their management of depression, that is designed to reliably and causally change processes that govern behavior [34]. An example of an active ingredient for depression could be a goal-setting task, a breathing exercise, or a recording of daily mood. Apps targeting other mental health illnesses such as anxiety or post-traumatic stress disorder were not excluded as long as depression was addressed as well. We included both free of charge and paid apps. Browser-based treatments were not included. We excluded apps that only targeted professionals (e.g. Depression Psychopharmacology), only offered a diagnostic service (e.g. PHQ-9 Depression Test Questionnaire), only provided quotes or inspirational text (e.g. Depression Quote Wallpapers), or only conveyed information without the goal of eliciting behavior change or engaging with individuals (e.g. Psychology Book - 1000+ Amazing Psychology Facts).

Two authors (GWT, ADF) separately reviewed each app according to the inclusion and exclusion criteria. The interrater agreement was excellent indicated by a Cohen’s Kappa of 0.91. In case of disagreement, a consensus was reached via discussion. After this initial assessment, we ranked all included apps from the Apple App Store separately by their number of reviews and all included apps from the Google Play Store by their download category (e.g. 1,000,000+ and 500,000+ downloads).
We then separately identified the most popular apps available only from the Apple App Store, or available only from the Google Play Store, or available from both stores. For apps only available on the Apple App Store we selected the five most reviewed apps, as users rarely scroll past the first five apps [25]. For the Google Play Store, we used the download category of the app ranked fifth on the list (e.g. 500,000+ downloads). All apps in the 500,000+ download category were then included. For apps available on both app stores, we used the Google Play 500’000+ download category to determine inclusion, regardless of the number of reviews on the Apple App Store. Regardless of their number of downloads or reviews, we included all apps from the curated lists meeting the inclusion and not violating the exclusion criteria.

Data Analysis

Our evaluation covered the following areas: general information about the app, potential mechanisms for delivery of JITAI, and peer-reviewed evidence. We developed our evaluation framework before reviewing the apps and used the Covidence Systematic Review software (Veritas Health Innovation Ltd., Australia, version accessed August 2020) to review the apps. All of our questions are listed in the Codebook in Supplementary Table 1-5, along with the sources from which we derived them. Two raters (GWT, ADF) separately evaluated each included app as follows:

First, we gathered general information about the apps including the name of the provider, additional affiliated organizations (e.g. other companies, universities, governments, or NGOs), and time since last updated. Second, we reviewed the app’s website and recorded all publications provided and information about JITAI. Third, we searched for peer-reviewed publications on PubMed, Cochrane Register of Controlled Trials, PsycINFO, and Google Scholar using the search term [(Name AND App) OR (Name AND Application AND Smartphone)].

Fourth, we reviewed the full text of each study found on the website and the different databases. We excluded books, theses, systematic reviews evaluating several different apps, and clinical trial registrations. After this, each study was evaluated in line with prior work [35] including the year of publication, journal name, journal impact factor, the number of subjects, study purpose, and study design (i.e. Randomized control trial, open trial). We also extracted the information available about JITAI mechanism. We reviewed to what degree the apps could be considered JITAI by reviewing whether and to what degree relevant features (e.g. vulnerability) derived from the JITAI concept by Nahum-Shani, Smith [22] were implemented. We assessed how the support was tailored by reviewing the symptoms of depressions that were measured (derived from the ICD-10 and DSM-V), and the self-report data or sensor and device analytics (derived from related work [23], from the Android Developers Guide [36], and the iOS security Guide [37]) that were used. We also reviewed whether tailoring to traits (i.e. “tailoring-to-people” [21]) was used by checking for questions about demographics and social-economic status. Since JITAI mechanisms are proposed to increase the effectiveness or efficacy of apps [22] we reviewed whether the publications addressed effectiveness or efficacy and whether JITAI mechanisms were investigated in these publications.

Finally, we reviewed the app itself and extracted the information available about JITAI mechanisms. The results from each rater were compared and a consensus was reached by discussion if necessary. We reviewed each app in September 2020 and the process is illustrated in .
**Results**

We found 249 apps on the Apple App Store, 217 apps on the Google Play Store, 57 apps on both stores, and 135 apps on the curated list yielding a total of 658 apps. We removed 17 duplicates, 349 apps that did not mention depression, 123 apps with no active component, eight apps that were not accessible, one app not available in English, and one app targeting professionals. We ranked the apps found only on the Apple App Store based on their number of reviews and included the five most reviewed apps. We ranked the remaining apps found on the Google App Store and apps found in both stores according to their number of downloads category. The fifth most downloaded app on the Google App Store had a download category of 500,000+. Therefore, we included all apps found on the Google App Store and all apps available on the Apple App Store and Google Play Store with more than 500,000+ downloads yielding 17 apps. We included six apps from the curated lists that met the inclusion criteria of mentioning depression and did not violate the exclusion criteria, yielding a total of 28 apps. A flow chart of the results from the review process is illustrated in Figure 2.

**Figure 2: Inclusion and exclusion process of reviewed apps.**
Publications

We found 68 peer-reviewed publication for the 28 reviewed apps (see Appendix 1 and Appendix 2). We found at least one publication for 16 apps (n = 28, 57%), at least one peer-reviewed publication investigating the effectiveness for nine apps (n = 28, 32%), and at least one peer-reviewed publication investigating the effectiveness for five apps (n = 28, 18%). While 23 (34%) of the 68 publications investigated the effectiveness and 14 (21%) publications investigated the efficacy of the apps not one publication evaluated an increase of effectiveness or efficacy by using JITAI mechanisms. Extracted information from all reviewed publications can be found in Appendix 2.

Apps

The 28 apps included were rated 2,808,465 times, with each app being rated on average 100,302.32 times (STD = 279,723.5, Min = 127.00, Max = 1,229,623.00, Median = 8,109.00, IQR = 28,310.00). The average rating over all apps was 4.44 stars (STD = 0.34, Min = 3.40, Max = 4.95, Median = 4.50, IQR = 0.37) out of possible 5 stars. The number of reviews and average reviews were calculated using weighted means with the information from the Apple App Store and Google Play Store if available. Table 1 summarizes the 28 apps that were included in the review and evaluated.

Table 1. General information and JITAI mechanisms of the reviewed apps.
| App                      | OS   | Number Reviews | AVR | NODC | Symptoms measured, measurements used                                      | NDS Used | NSR Used | NSDA Used |
|--------------------------|------|----------------|-----|------|---------------------------------------------------------------------------|----------|----------|-----------|
| Calm                     | AND, iOS | 1,229,623     | 4.71 | 10,000,000+                  | Activity, Mood, Unhelpful Beliefs, Sleep, Open Questions, Multiple Choice | 4        | 2        | -         |
| Headspace                | AND, iOS | 872,025       | 4.86 | 10,000,000+                  | -                                                      | -        | -        | -         |
| Daylio                   | AND, iOS | 328,048       | 4.62 | 10,000,000+                  | Activity, Mood, Appetite, Sleep, Ratings, Multiple Choice | 4        | 2        | -         |
| Youper                   | AND, iOS | 61,478        | 4.67 | 1,000,000+                   | Activity, Mood, Interest/Pleasure, Sleep, Vital Signs, Location, Open Questions, Ratings, Multiple Choice | 4        | 3        | 2         |
| Moodpath                 | AND, iOS | 57,011        | 4.64 | 1,000,000+                   | Activity, Mood, Interest/Pleasure, Appetite, Unhelpful Beliefs, Concentration, Sleep, Vital Signs, Open Questions, Ratings, Multiple Choice | 7        | 3        | 1         |
| Wysa                     | AND, iOS | 56,520        | 4.70 | 1,000,000+                   | Activity, Mood, Interest/Pleasure, Unhelpful Beliefs, Concentration, Sleep, Vital Signs, Open Questions, Ratings, Multiple Choice | 5        | 2        | -         |
| Friend Shoulder          | AND, iOS | 32,847        | 4.30 | 1,000,000+                   | Mood, Unhelpful Beliefs, Suicidal Thoughts, Open Questions | 3        | 1        | -         |
| BetterHelp               | AND, iOS | 30,592        | 4.63 | 500,000+                     | Mood, Unhelpful Beliefs, Suicidal Thoughts, Open Questions | 3        | 1        | -         |
| Sanvello                 | AND, iOS | 27,536        | 4.67 | 1,000,000+                   | Activity, Mood, Interest/Pleasure, Unhelpful Beliefs, Concentration, Sleep, Microphone, Open Questions, Ratings | 6        | 2        | 1         |
| 7 Cups                   | AND, iOS | 20,709        | 4.29 | 1,000,000+                   | Mood, Interest/Pleasure, Cognition, Unhelpful Beliefs, Distorted Perception, Open Questions, Ratings | 5        | 2        | -         |
| Control and Monitor      | AND, iOS | 16,149        | 4.50 | 1,000,000+                   | Activity, Mood, Appetite, Unhelpful Beliefs, Suicidal Thoughts, Sleep, Ratings, Multiple Choice | 6        | 2        | -         |
| #SelfCare                | AND, iOS | 14,670        | 4.57 | 500,000+                     | -                                                      | -        | -        | -         |
| Remente                  | AND, iOS | 11,494        | 4.34 | 1,000,000+                   | Activity, Mood, Open Questions, Ratings, Multiple Choice | 2        | 3        | -         |
| Reflexio                 | AND, iOS | 8118          | 4.30 | 1,000,000+                   | Mood, Open Questions, Ratings                          | 1        | 2        | -         |
| Moodnotes                | iOS    | 8100          | 4.70 | -                            | Mood, Illogical Thinking, Camera, Open Questions, Ratings, Multiple Choice | 2        | 3        | 1         |
| Online therapy - mental help | AND, iOS | 5979        | 4.40 | 500,000+                     | Mood, Unhelpful Beliefs, Suicidal Thoughts, Open Questions | 3        | 1        | -         |
| InnerHour                | AND, iOS | 5402          | 4.50 | 500,000+                     | Activity, Mood, Interest/Pleasure, Unhelpful Beliefs, Concentration, Suicidal Thoughts, Sleep, Ratings, Multiple Choice | 8        | 2        | -         |
| Happify                  | AND, iOS | 5164          | 4.21 | 500,000+                     | Activity, Mood, Interest/Pleasure, Cognition, Unhelpful Beliefs, Sleep, Distorted Perception, Camera, Open Questions, Ratings, Multiple Choice | 8        | 3        | 2         |
| What’s Up? - A Mental Health App | AND, iOS | 3446        | 4.22 | 500,000+                     | Activity, Mood, Interest/Pleasure, Open Questions, Ratings, Multiple Choice | 3        | 3        | -         |
| MoodTools - Depression Aid | AND, iOS | 3167        | 4.31 | 100,000+                     | Activity, Mood, Interest/Pleasure, Appetite, Cognition, Unhelpful Beliefs, Concentration, Suicidal Thoughts, Sleep, Distorted Perception, Ratings, Multiple Choice, Patient Health Questionnaire | 10       | 3        | -         |
| CBT Coach                | AND, iOS | 3067          | 4.95 | 10,000+                      | Activity, Mood, Interest/Pleasure, Appetite, Unhelpful Beliefs, Concentration, Suicidal Thoughts, Sleep, Ratings, Multiple Choice, Patient Health Questionnaire | 8        | 3        | -         |
| CBT Thought Diary        | AND, iOS | 2182          | 4.58 | 100,000+                     | Mood, Distorted Perception, Open Questions, Ratings, Multiple Choice | 2        | 3        | -         |
| T2 Mood Tracker          | AND, iOS | 1873          | 3.40 | 100,000+                     | Activity, Mood, Cognition, Unhelpful Beliefs, Concentration, Sleep, Open Questions, Ratings | 6        | 2        | -         |
| Joyable                  | AND    | 1522          | 4.48 | 5000+                         | Activity, Mood, Interest/Pleasure                      | 7        | 3        | -         |
| iOS     | Rating | Downloads | PTS   | Measurements                        | Count | Median | Min | Max | IQR |
|---------|--------|-----------|-------|-------------------------------------|-------|--------|-----|-----|-----|
| Breeze | iOS    | 1313      | 4.70  | Activity, Mood, Ratings, Multiple Choice | 2     | 127    | 3.91| 28  | 28  |
| Moodit | iOS    | 159       | 4.40  | Activity, Mood, Appetite, Sleep, Open Questions, Ratings, Multiple Choice | 4     | 144    | 3.66| 50,000+ | 5000 |
| Catch It | AND, iOS | 144    | 4.40  | Mood, Open Questions, Ratings, Multiple Choice | 1     | 127    | 3.91| 10,000+ | 1 |
| Feeling Good | AND, iOS | 127 | 3.91  | -                                        | -     | -      | -   | -   | -   |

Sum: 2,808,465, 124.22, 42,375,000, -114, 59, 7
Count: 28, 28, 25, -25, 25, 5
Mean: 100,302.3, 4.44, 1,695,000, -4.56, 2.36, 1.4
STD: 279,723.5, 0.34, 3,153,748,43, -2.47, 0.7, 0.55
Min: 127, 3.40, 5000, -1, 1, 1
Max: 1,229,623, 4.95, 10,000,000, -10, 3, 2
Median: 8109, 4.50, 500,000, -4, 2, 1
IQR: 28,310, 0.37, 900,000, -3, 1, 1

*aOS: Operating System, AND: Android
bAVR: average review out of five possible stars.
cNODC: number of downloads category
dNDS used: number of depression symptoms Used
eNSR used: number of self-reports used
fNSDA used: number of sensors and device analytics used

**JITAI mechanisms**

>We found that 25 (n = 28, 89%) of the reviewed apps measured some kind of depression symptoms when interacting with the app (e.g. initial assessment when starting the app). Three apps (n=28, 11%) did not use any measurements, 20 apps (n = 28, 71%) used at least one self-report (e.g. daily report of mood changes via a rating), while five apps (n = 28, 18%) used self-reports and sensors and devices analytics (e.g. taking a picture associated with a mood). Figure 3 illustrates how many depression symptoms were measured by different self-reports or sensors and device analytics for each of the reviewed apps. Mood Tools - Depression Aid measured the most depression symptoms (ten different symptoms measured) while not using any sensors and device analytics. Happify and Youper measured fewer depression symptoms (eight and four respectively) but used two different sensors and device analytics.

**Figure 3: Depressive symptoms measured and frequency of measurements used for each of the 28 reviewed apps.**
Our findings regarding the usage of self-reports and sensors and device analytics are summarized in Figure 5. In total we found that a symptom was measured by a self-report or sensors and device analytics 196 times. To measure different depressive symptoms self-reports were used almost exclusively with 189 times (n = 196, 96%) and sensors and device analytics were rarely used with seven times (n = 196, 4%). The self-reports used most frequently to measure different depressive symptoms were closed questions consisting of ratings, Likert-scales, and multiple-choice questions with 151 times (n = 196, 77%). Open questions were used 38 times (n = 196, 19%). The sensors and device analytics that were used most frequently were vital signs (mostly heart rate) and camera with each used two times (respectively n = 196, 1%). The symptom that was used most frequently was mood with 59 times (n = 196, 30%), followed by activity which was measured 31 times (n = 196, 16%). Unhelpful beliefs and sleep were measured 23 (n = 196, 12%) and 20 (n = 196, 10%) times.

**Figure 4: Heatmap of measurements used to measure symptoms.** The heatmap illustrates the number of times symptoms of depression were measured by self-reports or sensors and devices analytics summarized over the 28 reviewed apps. A darker color illustrates a higher number of occurrences, also indicated by the annotation in the cells.
When possible, we tried to match the measurement of the depressive symptom to a mechanism relevant to the JITAI concept. We were able to do so for state of vulnerability, proximal outcomes, distal outcomes, and tailoring variables. Some of the measurements could have been used for two or three JITAI mechanisms. Therefore, double counting of the symptoms and measurements for each mechanism is possible. Figure 5 illustrates our findings, including which measurements were used to measure which symptom and for which JITAI feature. The figure shows that some sensors and device analytics were not used as a passive measurement but rather to actively capture changes. For example, the camera was used as a measurement for activity by asking the users to take pictures of locations that they had been to or to take a picture of something that made them sad to describe their mood.

Figure 5: Connection between JITAI mechanisms, symptoms, and measurements. Sankey-Diagram illustrating for which of the different JITAI mechanisms (state of vulnerability, proximal outcomes, distal outcomes, tailoring variables) we were able to match a depressive symptom (e.g. mood), and the measurements used to capture the changes (e.g. closed question). The JITAI mechanisms are displayed in blue, depressive symptoms in orange, green, and purple, and measurements in grey. The size of the rectangle indicates the number of times the mechanism, symptom, or measurement was found. The thickness of the connection indicates the number of times a measurement or symptom was used. Some measurements have been assigned to two or three JITAI mechanisms and double counting is therefore possible.
Discussion

Principal Results

We reviewed the 28 most popular or recommended apps for depression found on the Apple App Store, Google Play Store, and in curated lists of respected authorities for mental health. Regarding our main aim to investigate JITAI's mechanisms, we found that not one of the reviewed apps specifically mentioned the use of JITAI mechanisms in the app, on their websites, or in the identified peer-reviewed publications. We found that three apps (n = 28, 11%) did not use any measurements and 20 apps (n = 28, 71%) only used self-reports (96% of all 196 measurements were self-reports). While such self-reports can be used as “in the moment assessments” (i.e. Ecological Momentary Assessments) that are closely related to the JITAI concept [24] we argue that they are insufficient to leverage the full potential of JITAI. We found that five apps (n = 28, 18%) also used sensors and device analytics (4% of all 196 measurements were sensor and device analytics). However, we found that most sensors such as the camera were used as “in the moment” assessments or as part of an app’s features and not to tailor the content or timing. Some of the apps measured depressive symptoms by self-reports when the app was first opened to determine what content should be presented (e.g. measuring the need to focus on sleep and mood). This type of static tailoring has been observed to be less effective than dynamic tailoring [38] and is in our view not sufficient for an app to be considered as a JITAI.

Interestingly, we found that besides mood (30% of all 196 times a symptom was measured) or decreased activity (16% of all 196 times a symptom was measured) other symptoms of depression were measured less frequently. Given the broad variety and severity of depression [39] and the high comorbidity with other mental health problems such as anxiety [40], this
focus on a subset of symptoms may not be sufficient to detect changes that might indicate a need for support. Additionally, a focus on the improvement of main symptoms (e.g. mood and activity derived from the DSM-V) may not be ample to contribute to the understanding of the complex processes involved in depression. Accurate and continuous measures of psychophysiological changes enabled by passive measurements of various physiological features (e.g. changes in breathing patterns or vital signs), may, however, improve the understanding of depression in general. Such an understanding could in turn enable an even more successful implementation of JITAI. Our findings highlight that while the JITAI concept appears to be widely known in the scientific digital health community [24] and different studies outline the possibility of detecting changes in depression or depressive symptoms such as mood by using different passive measurements [41-48] these mechanisms, surprisingly, have not been implemented in the real world aside from baseline or progress assessments.

Related to these findings, we were interested to what degree the effectiveness and efficacy was investigated in peer-reviewed publications since JITAI are proposed to increase the effectiveness or efficacy of apps. In none of the 68 reviewed publications JITAI mechanisms were investigated. Therefore, our findings highlight that the proposed increase of effectiveness or efficacy by using JITAI mechanisms is not evaluated in settings using real-world apps. Additionally, we found great variability of scientific evidence of the reviewed apps despite an increased interest in digital health, and several publications addressing this topic, especially within the last five years [26, 49, 50].

Limitations

The strengths of this study are the large number of apps initially screened, the analyses along a framework developed from existing work, the rigorous methodology of reviewing all identified studies addressing the apps, the apps’ websites, and the apps themselves. Nonetheless, it has several limitations. We reviewed the apps at a single point, which is a shortcoming found in related work as well. We are aware that the app stores are dynamic with constant changes [25] but a long-term review of the apps would have not been feasible. We may address this in our future work. Besides the lists we reviewed from the Anxiety and Depression Association of America, the National Health Service, and the American Psychological Association other organizations offer a rating system or a list of reviewed apps. These include but are not limited to the American Psychiatric Associations, PsyberGuide, and iMedicalApps. We did not review these lists as we expected a high number of overlaps and the fact that not all of the apps found on the lists were reviewed (e.g. Dartmouth PATH was not reviewed on Psyberguide, last checked, 27th of January, 2021), and that not all of the apps mentioned on the lists were recommended (e.g. Mood Watch Review, with low credibility, user experience, and transparency ratings on Psyberguide, last checked, 27th of January, 2021). We, however, see the value in a central platform for reviews of mental help apps and would suggest incorporating findings regarding the use of JITAI mechanisms into the existing review criteria. Finally, the review of the apps initially included other aspects such as the usage of evidence-based treatment, conversational agents, and the revenue model. Reporting these findings would have exceeded the scope of this review.

Comparison with Prior Work

We found eleven reviews investigating different aspects of apps addressing depression. Six of these reviews assessed the content or features of the apps, with one of the six adjusting their analysis to the number of users. The remaining studies investigated usability, adherence to clinical guidelines, claims, or data sharing and privacy practice. One meta-analytic review
investigated effect sizes of just-in-time adaptive interventions compared to control groups or other interventions but this review did not focus on apps or mental health. We found no study investigating the use of JITAI mechanisms or review of measurements used to capture changes of relevant features in apps. Furthermore, we did not find any studies reviewing whether real-world apps provide evidence for improving their effectiveness or efficacy by using JITAI mechanisms.

Conclusions
In conclusion, our findings indicate that due to the limited use of measurements for depressive symptoms, with the exception of self-reports as indicators for progress or initial tailoring, the 28 most popular or recommended apps addressing depression cannot be considered to be JITAI. An increase in effectiveness or efficacy by using JITAI mechanisms was also not evaluated by any of the reviewed publications. Due to these findings, we argue that the reviewed apps do not yet leverage the full potential of digital health interventions by providing tailored support when it is most needed and in a most helpful way.

Acknowledgements
We would like to thank Jacqueline Louise Mair for reviewing the manuscript and providing feedback.

GWT designed the evaluation framework with inputs from TK and ADF. GWT and TK designed and implemented the search strategy. GWT and ADF screened and coded the apps, websites, and studies, and extracted the data. GWT analyzed the data and drafted the initial manuscript supervised by TK. BK, NCJ, ASS, LTC, and EF provided methodological guidance and feedback on the manuscript. All authors reviewed and approved the final manuscript.

This work has been partially supported by the National Institute of Mental Health (R01 MH123482) and in part by CSS Insurance, Switzerland. The National Institute of Mental Health and CSS Insurance had no role in the study design, data collection, data analysis and interpretation, writing the manuscript, or reviewing and approving the manuscript for publication.

The reviewed apps and reviewed studies are publicly available. The extracted data used in this review will be shared full open access beginning three months and ending 24 months following study publication. For further questions or material request please contact gteepe@ethz.ch.

Conflicts of Interest
GWT, EF, and TK are affiliated with the Centre for Digital Health Interventions (www.c4dhi.org), a joint initiative of the Department of Management, Technology, and Economics at ETH Zurich and the Institute of Technology Management at the University of St. Gallen, which is funded in part by the Swiss health insurer CSS. EF and TK are also cofounders of Pathmate Technologies, a university spin-off company that creates and delivers digital clinical pathways. However, Pathmate Technologies is not involved in this study. NCJ and Dartmouth College are the owners of a depression and anxiety application entitled “Mood Triggers”. Despite this, owning Mood Triggers is not a financial conflict of interest given that Mood Triggers is not intended to be revenue-generating, but rather used to deliver and evaluate no-cost scalable treatment treatments using just-in-time adaptive interventions.
Abbreviations
ADAA: Anxiety and Depression Association of America
APA: American Psychological Association
JITAI: Just-in-time adaptive intervention
NHS: National Health Service
Multimedia Appendix

Appendix 1. Number of studies and type of studies found for each app.

| App            | Studies | Number Participants | Number of Randomized controlled trials | Number of Effectiveness Studies | Number of Efficacy Studies | Studies Comparing App to Other Treatment |
|----------------|---------|---------------------|----------------------------------------|---------------------------------|---------------------------|-------------------------------------------|
| Calm           | 10      | 24,332              | 1                                      | 1                               | 3                         | -                                         |
| Headspace      | 28      | 3,871               | 15                                     | 14                              | 6                         | 3                                         |
| Daylio         | 3       | 14                  | -                                      | -                               | 1                         | -                                         |
| Youper         | -       | -                   | -                                      | -                               | -                         | -                                         |
| Moodpath       | 1       | 6,675               | -                                      | -                               | -                         | -                                         |
| Wysa           | 3       | 129                 | -                                      | 1                               | -                         | -                                         |
| Friend Shoulder| -       | -                   | -                                      | -                               | -                         | -                                         |
| BetterHelp     | 1       | 318                 | -                                      | 1                               | -                         | -                                         |
| Sanvello       | 2       | 538                 | 1                                      | 2                               | -                         | 1                                         |
| 7 Cups         | 4       | 909                 | -                                      | 1                               | -                         | 1                                         |
| Control and Monitor #SelfCare | - | - | - | - | - | - |
| Remente        | -       | -                   | -                                      | -                               | -                         | -                                         |
| Reflexio       | -       | -                   | -                                      | -                               | -                         | -                                         |
| Moodnotes      | -       | -                   | -                                      | -                               | -                         | -                                         |
| Online therapy [...] | - | - | - | - | - | - |
| InnerHour      | 1       | -                   | -                                      | -                               | -                         | -                                         |
| Happify        | 5       | 155,352             | 1                                      | 3                               | 1                         | -                                         |
| What’s Up? [...] | - | - | - | - | - | - |
| MoodTools [...] | 1 | 26 | - | - | - | - |
| DBT Coach      | 2       | 38                  | -                                      | -                               | -                         | -                                         |
| CBT Thought Diary | - | - | - | - | - | - |
| T2 Mood Tracker | 3 | 215 | - | - | - | - |
| Joyable        | 1       | 3384                | -                                      | -                               | -                         | -                                         |
| Joyable        | 1       | 3384                | -                                      | -                               | -                         | -                                         |
| Breeze         | -       | -                   | -                                      | -                               | -                         | -                                         |
| Moodkit        | 2       | 278                 | 2                                      | 2                               | 1                         | -                                         |
| Catch It       | 1       | 285                 | -                                      | -                               | -                         | -                                         |
| Feeling Good   | -       | -                   | -                                      | -                               | -                         | -                                         |
| Sum            | 68      | 196,364             | 20                                     | 23                              | 14                        | 5                                         |
| Count          | 16      | 15                  | 5                                      | 9                               | 5                         | 4                                         |
| Mean           | 4.25    | 13,090.93           | 4                                      | 2.56                            | 2.8                       | 1.25                                      |
| STD            | 6.74    | 39,846.25           | 6.14                                   | 3.61                            | 2.49                      | 0.5                                       |
| Min            | 1       | 14                  | 1                                      | 1                               | 1                         | 1                                         |
| Max            | 28      | 155,352             | 15                                     | 12                              | 7                         | 2                                         |
| Median         | 2       | 318                 | 1                                      | 1                               | 2                         | 1                                         |
| IQR            | 2.25    | 3,455.50            | 1                                      | 1                               | 2                         | 0.25                                      |

Appendix 2. List of the reviewed publications.

| App            | Study             | N   | Type of Study         | Focus     | Comparison to Treatment |
|----------------|-------------------|-----|-----------------------|-----------|-------------------------|
| Calm           | Huberty et al (2019)[51] | 88  | Randomized control trial | Efficacy  | No                      |
| Study                      | Year | Type                  | Design               | Outcome        | Comparison                                      |
|----------------------------|------|-----------------------|----------------------|----------------|------------------------------------------------|
| Calm Huberty et al (2019)  | 52   | Parallel group        | Feasibility          | No             |
| Calm Huberty et al (2019)  | 53   | Parallel group        | Qualitative evaluation | No             |
| Calm Huberty et al (2019)  | 54   | One-time assessment   | Demographics, clinical characteristics, and usage patterns | No             |
| Calm Huberty et al (2020)  | 55   | One-time assessment   | Qualitative evaluation | No             |
| Calm Puzia et al (2020)    | 56   | Parallel group        | Efficacy             | Compared to treatment as usual |
| Calm Huberty et al (2020)  | 57   | Cross-sectional study | Qualitative evaluation | No             |
| Calm Clarke et al (2020)   | 58   | Pre-post-test, no control group | Efficacy | No             |
| Calm Callender et al (2019) | 59  | A-B single case research design | Effectiveness | No             |
| Calm Puzia et al (2020)    | 60   | One-time assessment   | Engagement           | No             |
| Headspace Howells et al (2016) | 61 | Randomized control trial | Effectiveness | Compared to other apps |
| Headspace Lim et al (2015)  | 62   | Randomized experimental study | Efficacy | No             |
| Headspace Taylor et al (2016) | 63 | Pre-post-test, no control group | Qualitative evaluation | No             |
| Headspace Laurie et al (2016) | 64 | Qualitative semi-structured interview | Qualitative evaluation | No             |
| Headspace Wen et al (2017)  | 65   | Pre-post-test, no control group | Effectiveness | No             |
| Headspace Wydell et al (2017) | 66 | Pre-post-test, no control group | Effectiveness | Compared to intervention |
| Headspace Mistler et al (2017) | 67 | Pre-post-test, no control group | Feasibility | No             |
| Headspace Bennike et al (2017) | 68 | Randomized control trial | Efficacy | Compared to other apps |
| Headspace Kubo et al (2018) | 69   | Pre-post-test, no control group | Feasibility | No             |
| Headspace Noone et al (2018) | 70  | Randomized control trial | Effectiveness | Compared to sham meditation |
| Headspace Yang et al (2018) | 71   | Randomized control trial | Effectiveness | Compared to waitlist |
| Headspace Economides et al (2018) | 72 | Randomized control trial | Effectiveness | No             |
| Headspace DeSteno et al (2018) | 73 | Randomized experimental study | Efficacy | No             |
| Headspace Rosen et al (2018) | 74  | Randomized control trial | Efficacy | Compared to waitlist |
| Headspace Champion et al (2018) | 75 | Randomized control trial | Effectiveness | Compared to waitlist |
| Headspace Kubo et al (2019) | 76   | Randomized control trial | Efficacy | Compared to treatment as usual |
| Headspace Flett et al (2020) | 77  | Randomized control trial | Effectiveness | Compared to waitlist |
| Headspace Collins et al (2019) | 78 | Randomized experimental study | Efficacy | No             |
| Headspace Bostock et al (2019) | 79 | Randomized control trial | Effectiveness | Compared to waitlist |
| Headspace Bostock et al (2019) | 79 | Randomized control trial | Effectiveness | Compared to other apps |
| Headspace Kirk et al (2019)  | 80   | Randomized experimental study | Efficacy | Compared to other apps and control |
| Headspace Quinones et al (2019) | 81 | Randomized control trial | Effectiveness | Compared to other apps and control |
| Headspace Bjorkstrand et al (2019) | 82 | Randomized control trial | Effectiveness | Compared to waitlist |
| Headspace Flett et al (2019) | 83   | Randomized control trial | Adherence            | No             |
| Headspace Avalos et al (2020) | 84 | Pre-post-test, no control group, no randomization | Feasibility | No             |
| Headspace Nibold et al (2020) | 85 | Multi-source field study | Gains in leadership | No             |
| Headspace Runge et al (2020) | 86  | Pre-post-test, no control group | Feasibility | No             |
| Headspace Ball et al (2020)  | 87   | Randomized control trial | Qualitative evaluation | Compared to treatment as usual |
| Daylio Hissain et al (2020) | 88   | Lab experiment, no Efficacy | No             |
| Application | Authors [Year] | Study Design | Outcome | Details |
|-------------|---------------|--------------|---------|---------|
| Daylio | Cristol et al (2018) [89] | - | Viewpoint | Patients Perspective | No |
| Daylio | Chaudhry et al (2016) [90] | - | Viewpoint | App's characteristics | No |
| Moodpath | Scherr et al (2019) [91] | 6675 | Study, no randomization, no control group | Health-seeking behavior | No |
| Wysa | Inkster et al (2018) [92] | 129 | Pre-post-test, no control group | Effectiveness | No |
| Wysa | Kretzschmar et al (2019) [93] | - | Viewpoint | Ethical Perspective | No |
| BetterHelp | Marcelle et al (2019) [95] | 318 | Pre-post-test, no control group | Effectiveness | No |
| Sanvello | Moberg et al (2019) [96] | 500 | Randomized control trial | Effectiveness | Compared to waitlist |
| Sanvello | Broglia et al (2019) [97] | 38 | Two-arm, parallel, nonrandomized | Effectiveness | Compared to receiving face-to-face treatment |
| 7 Cups | Baemel et al (2015) [98] | 866 | One-time assessment | Qualitative evaluation | Compared to satisfaction in psychotherapy |
| 7 Cups | Baemel et al (2016) [99] | 14 | One-time assessment | Qualitative evaluation | No |
| 7 Cups | Baemel et al (2018) [100] | 19 | Pre-post-test, no control group, no randomization | Effectiveness | No |
| 7 Cups | Baemel et al (2016) [101] | 10 | One-time assessment | Overall quality of app and listeners' knowledge and confidence | No |
| InnerHour | Malik et al (2020) [102] | - | Viewpoint | Feasibility | No |
| Happify | Carpenter et al (2016) [103] | 152,747 | Pre-post-test, no control group, no randomization | Effectiveness | No |
| Happify | Parks et al (2018) [104] | 1053 | Randomized control trial | Effectiveness | Compared to psychoeducation |
| Happify | Williams et al (2018) [105] | 591 | Parallel group | Resilience | Compared to psychoeducation |
| Happify | Hunter et al (2019) [106] | 140 | Randomized experimental study | Efficacy | Compared to psychoeducation |
| Happify | Parls et al (2020) [107] | 821 | Pre-post-test, no control group, no randomization | Effectiveness | No |
| MoodTools | Sarkar et al (2016) [108] | 26 | Lab experiment, no randomization | Usability | Compared to psychoeducation |
| DBT Coach | Rizvi (2011) [109] | 22 | Pre-post-test, no control group, no randomization | Feasibility | No |
| DBT Coach | Rizvi (2016) [110] | 16 | Pre-post-test, no control group, no randomization | Feasibility, acceptability, usability, and immediate effects | No, but treatment was offered as an adjunction to 6-month dialectical behavior therapy |
| T2 Mood Tracker | Bush (2014) [111] | 8 | One-time assessment | Feasibility | No |
| T2 Mood Tracker | Dewar (2016) [112] | 191 | Randomized experimental study | Reliability of a measure for motivation | No |
| T2 Mood Tracker | McCreight et al (2019) [113] | 16 | Evaluation using participatory design methods | Usability | No |
| Joyable | Dryman et al (2017) [114] | 3384 | Pre-post-test, no control group, no randomization | Effectiveness | No |
| Moodkit | Bakker et al (2018) [115] | 226 | Randomized control trial | Efficacy | Compared to waitlist |
| Moodkit | Dahne et al (2019) [116] | 52 | Randomized control trial | Efficacy | Compared to treatment as usual |
| Catch It | Kindermann et al (2016) [117] | 285 | Pre-post-test, no control group, no randomization | Effectiveness | No |

Sum: 196,364
Count: 63
Mean: 3,116.89
STD: 19,118.68
Min: 1
Max: 15,2747
Median - 112 - - -
IQR - 208.5 - - -

Comments: Mean, STD, Median, IQR calculated over count of all 68 identified studies.

References

1. World Health Organization. Depression and other common mental disorders: global health estimates. World Health Organization, 2017.
2. James SL, Abate D, Abate KH, Ayob SM, Abbafati C, Abbasi N, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet. 2018;392(10159):1789-858.
3. Cuijpers P, Stringaris A, Wolpert M. Treatment outcomes for depression: challenges and opportunities. Lancet Psychiatry. 2020 Nov;7(11):925-7. PMID: 32078823. doi: 10.1016/S2215-0366(20)30036-5.
4. Delgadillo J, Gonzalez Salas Duhne P. Targeted prescription of cognitive–behavioral therapy versus person-centered counseling for depression using a machine learning approach. Journal of Consulting and Clinical Psychology. 2020;88(1):14.
5. Delgadillo J, Rubel J, Barkham M. Towards personalized allocation of patients to therapists. J Consult Clin Psychol. 2020 Sep;88(9):799-808. PMID: 32378910. doi: 10.1037/ccp0000507.
6. Kazdin AE, Blase SL. Rebooting Psychotherapy Research and Practice to Reduce the Burden of Mental Illness. Perspect Psychol Sci. 2011 Jan;6(1):21-37. PMID: 26162113. doi: 10.1177/1745691610393527.
7. Andrade LH, Alonso J, Mneimneh Z, Wells J, Al-Hamzawi A, Borges G, et al. Barriers to mental health treatment: results from the WHO World Mental Health (WMH) Surveys. Psychological medicine. 2014;44(6):1303.
8. Gulliver A, Griffiths KM, Christensen H. Perceived barriers and facilitators to mental health help-seeking in young people: a systematic review. BMC Psychiatry. 2010 Dec 30;10(1):113. PMID: 21192795. doi: 10.1186/1471-244X-10-113.
9. World Health Organization. Global health workforce, finances remain low for mental health. 2015.
10. Wilhelm S, Weingarden H, Ladis I, Braddick V, Shin J, Jacobson NC. Cognitive-Behavioral Therapy in the Digital Age: Presidential Address. Behav Ther. 2020 Jan;51(1):1-14. PMID: 32005328. doi: 10.1016/j.beth.2019.08.001.
11. Fairburn CG, Patel V. The impact of digital technology on psychological treatments and their dissemination. Behaviour research and therapy. 2017;88:19-25.
12. Kazdin AE. Addressing the treatment gap: A key challenge for extending evidence-based psychosocial interventions. Behav Res Ther. 2017 Jan;88:7-18. PMID: 28110678. doi: 10.1016/j.brat.2016.06.004.
13. The Lancet Child Adolescent Health. Growing up in a digital world: benefits and risks. The Lancet Child & adolescent health. 2018;2(2):79.
14. Weisel KK, Fuhrmann LM, Berking M, Baumeister H, Cuijpers P, Ebert DD. Standalone smartphone apps for mental health-a systematic review and meta-analysis. NPJ Digit Med. 2019;2(1):118. PMID: 31815193. doi: 10.1038/s41746-019-0188-8.
15. Ebert DD, Van Daele T, Nordgreen T, Karekla M, Compare A, Zarbo C, et al. Internet-and mobile-based psychological interventions: applications, efficacy, and potential for improving mental health. European Psychologist. 2018.
16. Chisholm D, Sweeney K, Sheehan P, Rasmussen B, Smit F, Cuijpers P, et al. Scaling-up treatment of depression and anxiety: a global return on investment analysis. Lancet Psychiatry.

https://preprints.jmir.org/preprint/29412 [unpublished, non-peer-reviewed preprint]
17. Andrews G, Basu A, Cuijpers P, Craske M, McEvoy P, English C, et al. Computer therapy for the anxiety and depression disorders is effective, acceptable and practical health care: an updated meta-analysis. Journal of anxiety disorders. 2018;55:70-8.
18. Deady M, Choi I, Calvo RA, Glozier N, Christensen H, Harvey SB. eHealth interventions for the prevention of depression and anxiety in the general population: a systematic review and meta-analysis. BMC Psychiatry. 2017 Aug 29;17(1):310. PMID: 28851342. doi: 10.1016/j.bmcpsychi.2016.12.018.
19. Ebert DD, Zarski AC, Christensen H, Stikkelbroek Y, Cuijpers P, Berking M, et al. Internet and computer-based cognitive behavioral therapy for anxiety and depression in youth: a meta-analysis of randomized controlled outcome trials. PLoS One. 2015;10(3):e0119895. PMID: 25786025. doi: 10.1371/journal.pone.0119895.
20. Firth J, Torous J, Nicholas J, Carney R, Pratap A, Rosenbaum S, et al. The efficacy of smartphone-based mental health interventions for depressive symptoms: a meta-analysis of randomized controlled trials. World Psychiatry. 2017 Oct;16(3):287-98. PMID: 28941113. doi: 10.1002/wps.20472.
21. Nahum-Shani I, Hekler EB, Spruijt-Metz D. Building health behavior models to guide the development of just-in-time adaptive interventions: A pragmatic framework. Health Psychol. 2015 Dec;34:1209-19. PMID: 26651462. doi: 10.1037/hea0000306.
22. Nahum-Shani I, Smith SN, Spring BJ, Collins LM, Witkiewitz K, Tewari A, et al. Just-in-Time Adaptive Interventions (JITAI) in Mobile Health: Key Components and Design Principles for Ongoing Health Behavior Support. Ann Behav Med. 2018 May 18;52(6):446-62. PMID: 27663578. doi: 10.1007/s12160-016-9830-8.
23. Cornet VP, Holden RJ. Systematic review of smartphone-based passive sensing for health and wellbeing. J Biomed Inform. 2018 Jan;77:120-32. PMID: 29248628. doi: 10.1016/j.jbi.2017.12.008.
24. Wang L, Miller LC. Just-in-the-Moment Adaptive Interventions (JITAI): A Meta-Analytical Review. Health Commun. 2020 Nov;35(12):1531-44. PMID: 31488002. doi: 10.1080/10410236.2019.1652388.
25. Dogruel L, Joeckel S, Bowman ND. Choosing the right app: An exploratory perspective on heuristic decision processes for smartphone app selection. Mobile Media & Communication. 2015;3(1):125-44.
26. Baumel A, Torous J, Edan S, Kane JM. There is a non-evidence-based app for that: A systematic review and mixed methods analysis of depression-and anxiety-related apps that incorporate unrecognized techniques. Journal of Affective Disorders. 2020.
27. Wasil AR, Gillespie S, Patel R, Petre A, Venturo-Conerly KE, Shingleton RM, et al. Reassessing evidence-based content in popular smartphone apps for depression and anxiety: Developing and applying user-adjusted analyses. J Consult Clin Psychol. 2020 Nov;88(11):983-93. PMID: 32881542. doi: 10.1037/cmp0000604.
28. Number of venture capital-backed digital health deals in selected countries in HY1 2019 [database on the Internet]. 2019 [cited 2020 January 29]. Available from: https://www.mobihalthnews.com/news/2019-closes-year-251-digital-health-fundings.
29. Mobile Operating System Market Share Worldwide [database on the Internet]. statcounter Global Stats. 2020 [cited 2020 April 4]. Available from: https://gs.statcounter.com/os-market-share/mobile/worldwide.
30. ADAA Reviewed Mental Health Apps [database on the Internet]. 2020 [cited 2020 July 04]. Available from: https://adaa.org/finding-help/mobile-apps.
31. NHS Apps Libary [database on the Internet]. NHS. 2020 [cited 2020 July 04]. Available from: https://www.nhs.uk/apps-library/.
32. Mobile Apps and Websites [database on the Internet]. APA. 2020 [cited 2020 July 04]. Available from: https://www.apa.org/careers/early-career/useful-apps?tab=3.
33. Michie S, Ashford S, Sniehotta FF, Dombrowski SU, Bishop A, French DP. A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: the CALO-RE taxonomy. Psychology & health. 2011;26(11):1479-98.
34. Carey RN, Connell LE, Johnston M, Rothman AJ, de Bruin M, Kelly MP, et al. Behavior Change Techniques and Their Mechanisms of Action: A Synthesis of Links Described in Published Intervention Literature. Ann Behav Med. 2019 Jul 17;53(8):693-707. PMID: 30304386. doi: 10.1093/abm/kay078.
35. Safavi K, Mathews SC, Bates DW, Dorsey ER, Cohen AB. Top-funded digital health companies and their impact on high-burden, high-cost conditions. Health Affairs. 2019;38(1):115-23.
36. Sensors Overview [database on the Internet]. 2020 [cited 2020 July 07]. Available from: https://developer.android.com/guide/topics/sensors/sensors_overview.
37. iOS Security Guide [database on the Internet]. 2020 [cited 2020 July 07]. Available from: https://support.apple.com/en-gb/guide/security/welcome/web.
38. Krebs P, Prochaska JO, Rossi JS. A meta-analysis of computer-tailored interventions for health behavior change. Prev Med. 2010 Sep-Oct;51(3-4):214-21. PMID: 20558196. doi: 10.1016/j.ypmed.2010.06.004.
39. Mitchell AJ, Vaze A, Rao S. Clinical diagnosis of depression in primary care: a meta-analysis. Lancet. 2009 Aug 22;374(9690):609-19. PMID: 19640579. doi: 10.1016/S0140-6736(09)60879-5.
40. Jacobson NC, Newman MG. Anxiety and depression as bidirectional risk factors for one another: A meta-analysis of longitudinal studies. Psychological bulletin. 2017;143(11):1155.
41. Jacobson NC, Weingarden H, Wilhelm S. Using Digital Phenotyping to Accurately Detect Depression Severity. The Journal of nervous and mental disease. 2019;207(10):893-6.
42. Jacobson NC, Weingarden H, Wilhelm S. Digital biomarkers of mood disorders and symptom change. NPJ Digit Med. 2019 2019/02/01;2(1):3. PMID: 31304353. doi: 10.1038/s41746-019-0078-0.
43. Jacobson NC, Chung YJ. Passive Sensing of Prediction of Moment-To-Moment Depressed Mood among Undergraduates with Clinical Levels of Depression Sample Using Smartphones. Sensors (Basel). 2020 Jun 24;20(12):3572. PMID: 32599801. doi: 10.3390/s20123572.
44. Saeb S, Lattie EG, Kording KP, Mohr DC. Mobile Phone Detection of Semantic Location and Its Relationship to Depression and Anxiety. JMIR Mhealth Uhealth. 2017 Aug 10;5(8):e112. PMID: 28798010. doi: 10.2196/mhealth.7297.
45. Saeb S, Lattie EG, Schueller SM, Kording KP, Mohr DC. The relationship between mobile phone location sensor data and depressive symptom severity. PeerJ. 2016;4:e2537.
46. Wahle F, Kowatsch T, Fleisch E, Rufer M, Weidt S. Mobile Sensing and Support for People With Depression: A Pilot Trial in the Wild. JMIR Mhealth Uhealth. 2016 Sep 21;4(3):e111. PMID: 27655245. doi: 10.2196/mhealth.5960.
47. Lu J, Shang C, Yue C, Morillo R, Ware S, Kamath J, et al. Joint modeling of heterogeneous sensing data for depression assessment via multi-task learning. Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies. 2018;2(1):1-21.
48. Osmani V. Smartphones in mental health: detecting depressive and manic episodes. IEEE Pervasive Computing. 2015;14(3):10-3.
49. Sucala M, Cuijpers P, Muench F, Cardoso R, Soflau R, Dobrean A, et al. Anxiety: There is an app for that. A systematic review of anxiety apps. Depression and anxiety. 2017;34(6):518-25.
50. Van Ameringen M, Turna J, Khalesi Z, Pullia K, Patterson B. There is an app for that! The current state of mobile applications (apps) for DSM-5 obsessive-compulsive disorder,
posttraumatic stress disorder, anxiety and mood disorders. Depression and anxiety. 2017;34(6):526-39.

51. Huberty J, Green J, Glissmann C, Larkey L, Puzia M, Lee C. Efficacy of the mindfulness meditation mobile app “Calm” to reduce stress among college students: Randomized controlled trial. JMIR mHealth and uHealth. 2019;7(6):e14273.

52. Huberty J, Eckert R, Larkey L, Kurka J, Rodriguez De Jesus SA, Yoo W, et al. Smartphone-Based Meditation for Myeloproliferative Neoplasm Patients: Feasibility Study to Inform Future Trials. JMIR Form Res. 2019 Apr 29;3(2):e12662. PMID: 31033443. doi: 10.2196/12662.

53. Huberty J, Eckert R, Larkey L, Joeman L, Mesa R. Experiences of using a consumer-based mobile meditation app to improve fatigue in myeloproliferative patients: qualitative study. JMIR cancer. 2019;5(2):e14292.

54. Huberty J, Vranceanu A-M, Carney C, Breus M, Gordon M, Puzia ME. Characteristics and usage patterns among 12,151 paid subscribers of the Calm meditation app: cross-sectional survey. JMIR mHealth and uHealth. 2019;7(11):e15648.

55. Huberty J, Puzia M, Eckert R, Larkey L. Cancer Patients’ and Survivors’ Perceptions of the Calm App: Cross-Sectional Descriptive Study. JMIR Cancer. 2020 Jan 25;6(1):e16926. PMID: 32039812. doi: 10.2196/16926.

56. Puzia ME, Huberty J, Eckert R, Larkey L, Mesa R. Associations between global mental health and response to an app-based meditation intervention in myeloproliferative neoplasm patients. Integrative cancer therapies. 2020;19:1534735420927780.

57. Huberty J, Puzia ME, Larkey L, Irwin MR, Vranceanu A-M. Use of the Consumer-Based Meditation App Calm for Sleep Disturbances: Cross-Sectional Survey Study. JMIR formative research. 2020;4(11):e19508.

58. Clarke J, Draper S. Intermittent mindfulness practice can be beneficial, and daily practice can be harmful. An in depth, mixed methods study of the “Calm” app’s (mostly positive) effects. Internet Interventions. 2020;19:100293.

59. Callender KA, Trustey CE, Alton L, Hao Y. Single Case Evaluation of a Mindfulness-Based Mobile Application with a Substance Abuse Counselor. Counseling Outcome Research and Evaluation. 2019:1-14.

60. Puzia M, Laird B, Green J, Huberty J. Parents’ Perceptions of Their Children’s Engagement in a Consumer-Based Meditation Mobile App: Cross-Sectional Survey Study. JMIR Pediatrics and Parenting. 2020;3(2):e24536.

61. Howells A, Ivitzan I, Eiroa-Orosa FJ. Putting the ‘app’in happiness: a randomised controlled trial of a smartphone-based mindfulness intervention to enhance wellbeing. Journal of Happiness Studies. 2016;17(1):163-85.

62. Lim D, Condon P, DeSteno D. Mindfulness and compassion: an examination of mechanism and scalability. PLoS One. 2015;10(2):e0118221. PMID: 25689827. doi: 10.1371/journal.pone.0118221.

63. Taylor M, Hageman JR, Brown M. A Mindfulness Intervention for Residents: Relevance for Pediatricians. Pediatr Ann. 2016 Oct 1;45(10):e373-e6. PMID: 27735974. doi: 10.3928/19382359-20160912-01.

64. Laurie J, Blandford A. Making time for mindfulness. Int J Med Inform. 2016 Dec;96:38-50. PMID: 26965526. doi: 10.1016/j.ijmedinf.2016.02.010.

65. Wen L, Sweeney TE, Welton L, Trockel M, Katznelson L. Encouraging Mindfulness in Medical House Staff via Smartphone App: A Pilot Study. Acad Psychiatry. 2017 Oct;41(5):646-50. PMID: 28795335. doi: 10.1007/s40596-017-0768-3.

66. Wylde CM, Mahrer NE, Meyer RM, Gold JI. Mindfulness for novice pediatric nurses: smartphone application versus traditional intervention. Journal of pediatric nursing. 2017;36:205-12.
67. Mistler LA, Ben-Zeev D, Carpenter-Song E, Brunette MF, Friedman MJ. Mobile Mindfulness Intervention on an Acute Psychiatric Unit: Feasibility and Acceptability Study. JMIR Ment Health. 2017 Aug 21;4(3):e34. PMID: 28827214. doi: 10.2196/mental.7717.

68. Bennike IH, Wieghorst A, Kirk U. Online-based mindfulness training reduces behavioral markers of mind wandering. Journal of Cognitive Enhancement. 2017;1(2):172-81.

69. Kubo A, Altschuler A, Kurtovich E, Hendlish S, Laurent CA, Kolevska T, et al. A Pilot Mobile-based Mindfulness Intervention for Cancer Patients and their Informal Caregivers. Mindfulness (N Y). 2018 Dec;9(6):1885-94. PMID: 30740187. doi: 10.1007/s12671-018-0931-2.

70. Noone C, Hogan MJ. A randomised active-controlled trial to examine the effects of an online mindfulness intervention on executive control, critical thinking and key thinking dispositions in a university student sample. BMC Psychol. 2018 Apr 5;6(1):13. PMID: 29622047. doi: 10.1186/s40359-018-0226-3.

71. Yang E, Schamber E, Meyer RML, Gold JI. Happier Healers: Randomized Controlled Trial of Mobile Mindfulness for Stress Management. J Altern Complement Med. 2018 May;24(5):505-13. PMID: 29420050. doi: 10.1089/acm.2015.0301.

72. Economides M, Martman J, Bell MJ, Sanderson B. Improvements in Stress, Affect, and Irritability Following Brief Use of a Mindfulness-based Smartphone App: A Randomized Controlled Trial. Mindfulness (N Y). 2018 2018/10/01;9(5):1584-93. PMID: 30294390. doi: 10.1007/s12671-018-0905-4.

73. DeSteno D, Lim D, Duong F, Condon P. Meditation inhibits aggressive responses to provocations. Mindfulness. 2018;9(4):1117-22.

74. Rosen KD, Paniagua SM, Kazanis W, Jones S, Potter JS. Quality of life among women diagnosed with breast Cancer: A randomized waitlist controlled trial of commercially available mobile app-delivered mindfulness training. Psycho-oncology. 2018;27(8):2023-30.

75. Champion L, Economides M, Chandler C. The efficacy of a brief app-based mindfulness intervention on psychosocial distress and adjustment to college in incoming university students: a pragmatic, randomised, waitlist-controlled trial. PLoS One. 2018;13(12):e0209482. PMID: 30596696. doi: 10.1371/journal.pone.0209482.

76. Kubo A, Kurtovich E, McGinnis M, Aghaei S, Altschuler A, Quesenberry Jr C, et al. A randomized controlled trial of mHealth mindfulness intervention for cancer patients and informal cancer caregivers: a feasibility study within an integrated health care delivery system. Integrative cancer therapies. 2019;18:1534735419850634.

77. Flett JAM, Conner TS, Riordan BC, Patterson T, Hayne H. App-based mindfulness meditation for psychological distress and adjustment to college in incoming university students: a pragmatic, randomised, waitlist-controlled trial. Psychol Health. 2020 Sep;35(9):1049-74. PMID: 32046499. doi: 10.1080/08870446.2019.1711089.

78. Collins E, Cox A, Wilcock C, Sethu-Jones G. Digital Games and Mindfulness Apps: Comparison of Effects on Post Work Recovery. JMIR Ment Health. 2019 Jul 18;6(7):e12853. PMID: 31322125. doi: 10.2196/12853.

79. Bostock S, Crosswell AD, Prather AA, Steptoe A. Mindfulness on-the-go: Effects of a mindfulness meditation app on work stress and well-being. J Occup Health Psychol. 2019 Feb;24(1):127-38. PMID: 29723001. doi: 10.1037/ocp0000118.

80. Kirk U, Wieghorst A, Nielsen CM, Staiano W. On-the-spot binaural beats and mindfulness reduces behavioral markers of mind wandering. Journal of Cognitive Enhancement. 2019;3(2):186-92.

81. Quinones C, Griffiths MD. Reducing compulsive Internet use and anxiety symptoms via two brief interventions: A comparison between mindfulness and gradual muscle relaxation. Journal of behavioral addictions. 2019;8(3):530-6.

82. Bjorkstrand J, Schiller D, Li J, Davidson P, Rosen J, Martensson J, et al. The effect of
mindfulness training on extinction retention. Sci Rep. 2019 Dec 27;9(1):19896. PMID: 31882606. doi: 10.1038/s41598-019-56167-7.
83. Flett JAM, Fletcher BD, Riordan BC, Patterson T, Hayne H, Conner TS. The peril of self-reported adherence in digital interventions: A brief example. Internet Interv. 2019 Dec;18:100267. PMID: 31890620. doi: 10.1016/j.invent.2019.100267.
84. Avalos LA, Aghaee S, Kurtovich E, Quesenberry C Jr, Nkemere L, McGinnis MK, et al. A Mobile Health Mindfulness Intervention for Women With Moderate to Moderately Severe Postpartum Depressive Symptoms: Feasibility Study. JMIR Ment Health. 2020 Nov 12;7(11):e17405. PMID: 33180028. doi: 10.2196/17405.
85. Nübold A, Van Quaquebeke N, Hülsheger UR. Be (com) ing real: A multi-source and an intervention study on mindfulness and authentic leadership. Journal of Business and Psychology. 2020;35(4):469-88.
86. Rung AL, Oral E, Berghammer L, Peters ES. Feasibility and acceptability of a mobile mindfulness meditation intervention among women: intervention study. JMIR mHealth and uHealth. 2020;8(6):e15943.
87. Ball E, Newton S, Rohricht F, Steed L, Birch J, Dodds J, et al. mHealth: providing a mindfulness app for women with chronic pelvic pain in gynaecology outpatient clinics: qualitative data analysis of user experience and lessons learnt. BMJ Open. 2020 Mar 12;10(3):e030711. PMID: 32165550. doi: 10.1136/bmjopen-2019-030711.
88. Hussain A, Mkpojiogu EO, Hussein I, Muhi OM, Yosri MHH. The Effectiveness, Efficiency and Reliability-in-Use of Daylio Mobile App.
89. Cristol S. Patient’s perspective on using mobile technology as an aid to psychotherapy. JMIR mental health. 2018;5(4):e10015.
90. Chaudhry BM. Daylio: mood-quantification for a less stressful you. Mhealth. 2016;2:34. PMID: 28293607. doi: 10.21037/mhealth.2016.08.04.
91. Scherr S, Goering M. Is a self-monitoring app for depression a good place for additional mental health information? Ecological momentary assessment of mental help information seeking among smartphone users. Health communication. 2019:1-9.
92. Inkster B, Sarda S, Subramanian V. An Empathy-Driven, Conversational Artificial Intelligence Agent (Wysa) for Digital Mental Well-Being: Real-World Data Evaluation Mixed-Methods Study. JMIR Mhealth Uhealth. 2018 Nov 23;6(11):e12106. PMID: 30470676. doi: 10.2196/12106.
93. Kretzschmar K, Tyroll H, Pavarini G, Manzini A, Singh I, NeurOx Young People's Advisory G. Can your phone be your therapist? Young people’s ethical perspectives on the use of fully automated conversational agents (chatbots) in mental health support. Biomedical Informatics Insights. 2019;11:117822619829083.
94. Inkster B, O'Brien R, Selby E, Joshi S, Subramanian V, Kadaba M, et al. Digital Health Management During and Beyond the COVID-19 Pandemic: Opportunities, Barriers, and Recommendations. JMIR Ment Health. 2020 Jul 6;7(7):e19246. PMID: 32484783. doi: 10.2196/19246.
95. Marcelle ET, Nolting L, Hinshaw SP, Aguilera A. Effectiveness of a Multimodal Digital Psychotherapy Platform for Adult Depression: A Naturalistic Feasibility Study. JMIR Mhealth Uhealth. 2019 Jan 23;7(1):e10948. PMID: 30674448. doi: 10.2196/10948.
96. Moberg C, Niles A, Beermann D. Guided Self-Help Works: Randomized Waitlist Controlled Trial of Pacifica, a Mobile App Integrating Cognitive Behavioral Therapy and Mindfulness for Stress, Anxiety, and Depression. J Med Internet Res. 2019 Jun 8;21(6):e12556. PMID: 31199319. doi: 10.2196/12556.
97. Broglia E, Millings A, Barkham M. Counseling with guided use of a mobile well-being app for students experiencing anxiety or depression: clinical outcomes of a feasibility trial
embedded in a student counseling service. JMIR mHealth and uHealth. 2019;7(8):e14318.
98. Baumel A. Online emotional support delivered by trained volunteers: users’ satisfaction and their perception of the service compared to psychotherapy. Journal of Mental Health. 2015;24(5):313-20.
99. Baumel A, Schueller SM. Adjusting an Available Online Peer Support Platform in a Program to Supplement the Treatment of Perinatal Depression and Anxiety. JMIR Ment Health. 2016 Mar 21;3(1):e11. PMID: 27001373. doi: 10.2196/mental.5335.
100. Baumel A, Tinkelman A, Mathur N, Kane JM. Digital peer-support platform (7Cups) as an adjunct treatment for women with postpartum depression: feasibility, acceptability, and preliminary efficacy study. JMIR mHealth and uHealth. 2018;6(2):e38.
101. Baumel A, Correll CU, Birnbaum M. Adaptation of a peer based online emotional support program as an adjunct to treatment for people with schizophrenia-spectrum disorders. Internet Interv. 2016 May;4:35-42. PMID: 30135788. doi: 10.1016/j.invent.2016.03.003.
102. Malik A, Kalidhar A, Hanon C. InnerHour: Solving the Treatment Gap in Mental Health. Using technology to disrupt the mental health landscape. L’information psychiatrique. 2020;96(5):348-54.
103. Carpenter J, Crutchley P, Zilca RD, Schwartz HA, Smith LK, Cobb AM, et al. Seeing the “big” picture: big data methods for exploring relationships between usage, language, and outcome in internet intervention data. Journal of medical Internet research. 2016;18(8):e241.
104. Parks AC, Williams AL, Tugade MM, Hokes KE, Honomichl RD, Zilca RD. Testing a scalable web and smartphone based intervention to improve depression, anxiety, and resilience: A randomized controlled trial. International Journal of Wellbeing. 2018;8(2).
105. Williams AL, Parks AC, Cormier G, Stafford J, Whillans A. Improving resilience among employees high in depression, anxiety, and workplace distress. Int J Manag Res. 2018;9(1-2):4-22.
106. Hunter JF, Olah MS, Williams AL, Parks AC, Pressman SD. Effect of Brief Biofeedback via a Smartphone App on Stress Recovery: Randomized Experimental Study. JMIR Serious Games. 2019 Nov 26;7(4):e15974. PMID: 31769761. doi: 10.2196/15974.
107. Parks AC, Williams AL, Kackloudis GM, Stafford JL, Boucher EM, Honomichl RD. The Effects of a Digital Well-Being Intervention on Patients With Chronic Conditions: Observational Study. J Med Internet Res. 2020 Jan 10;22(1):e16211. PMID: 31922491. doi: 10.2196/16211.
108. Sarkar U, Gourley GI, Lyles CR, Tieu L, Clarity C, Newmark L, et al. Usability of Commercially Available Mobile Applications for Diverse Patients. J Gen Intern Med. 2016 Dec;31(12):1417-26. PMID: 27418347. doi: 10.1007/s11606-016-3771-6.
109. Rizvi SL, Dimeff LA, Sketch J, Carroll D, Linehan MM. A pilot study of the DBT coach: an interactive mobile phone application for individuals with borderline personality disorder and substance use disorder. Behavior therapy. 2011;42(4):589-600.
110. Rizvi SL, Hughes CD, Thomas MC. The DBT Coach mobile application as an adjunct to treatment for suicidal and self-injuring individuals with borderline personality disorder: A preliminary evaluation and challenges to client utilization. Psychological services. 2016;13(4):380.
111. Bush NE, Ouellette G, Kinn J. Utility of the T2 Mood Tracker mobile application among army warrior transition unit service members. Military medicine. 2014;179(12):1453-7.
112. Dewar AR, Bull TP, Sproat JM, Reyes NP, Malvey DM, Szalma JL, editors. Testing the reliability of a measure of motivation to engage with telehealth technology. Proceedings of the Human Factors and Ergonomics Society Annual Meeting; 2016: SAGE Publications Sage CA: Los Angeles, CA.
113. McCreight SJ, Brinton C, Kinn J, Bush N, Hoyt T. Integration of mCare and T2 mood tracker: illustrating mHealth usability testing. Journal of Technology in Behavioral Science.
114. Dryman MT, McTeague LM, Olino TM, Heimberg RG. Evaluation of an open-access CBT-based Internet program for social anxiety: Patterns of use, retention, and outcomes. Journal of Consulting and Clinical Psychology. 2017;85(10):988.

115. Bakker D, Kazantzis N, Rickwood D, Rickard N. A randomized controlled trial of three smartphone apps for enhancing public mental health. Behav Res Ther. 2018 Oct;109:75-83. PMID: 30125790. doi: 10.1016/j.brat.2018.08.003.

116. Dahne J, Lejuez CW, Diaz VA, Player MS, Kustanowitz J, Felton JW, et al. Pilot Randomized Trial of a Self-Help Behavioral Activation Mobile App for Utilization in Primary Care. Behav Ther. 2019 Jul;50(4):817-27. PMID: 31208690. doi: 10.1016/j.beth.2018.12.003.

117. Kinderman P, Hagan P, King S, Bowman J, Chahal J, Gan L, et al. The feasibility and effectiveness of Catch It, an innovative CBT smartphone app. BJPsych Open. 2016 May;2(3):204-9. PMID: 27703777. doi: 10.1192/bjpo.bp.115.002436.
Supplementary Files
Figures
Review process for each app.

1. Review of information on Apple App Store and Google Play Store
   - Website
   - Downloads, number of reviews, average reviews, last-update

2. Review of app’s website
   - Publications provided
   - Involvement of professionals

3. Search for peer-reviewed publications
   - Databases: PubMed, Cochrane Register of Controlled Trials, PsycINFO, Google Scholar
   - Search term = (Name AND App) OR (Name AND Application AND Smartphone)

4. Review of each publication from the website and the databases
   - Exclusion: systematic reviews, books, BA/MA/PhD thesis, clinical trial registrations
   - Number of participants, year, journal, impact factor, measurements, measuring changes in symptoms of depression, comparison to other treatment, study design
   - Extraction of information about JITAI

5. Review of app itself
   - Extraction of information about JITAI

6. Comparison of results from each rater and reaching consensus by discussion if necessary
Inclusion and exclusion process of reviewed apps.
Depressive symptoms measured and frequency of measurements used for each of the 28 reviewed apps.
Heatmap of measurements used to measure symptoms. The heatmap illustrates the number of times symptoms of depression were measured by self-reports or sensors and devices analytics summarized over the 28 reviewed apps. A darker color illustrates a higher number of occurrences, also indicated by the annotation in the cells.

| Symptoms of Depression         | Self-Reports | Sensors and Device Analytics | Total |
|--------------------------------|--------------|-------------------------------|-------|
|                                | Activity     | Mood                         |       |
|                                 | 3            | 23                           | 26    |
|                                | 18           | 39                           | 57    |
|                                | 1            | 15                           | 16    |
|                                | 0            | 9                            | 9     |
|                                | 2            | 6                            | 8     |
|                                | 6            | 17                           | 23    |
|                                | 1            | 9                            | 10    |
|                                | 3            | 7                            | 10    |
|                                | 2            | 18                           | 20    |
|                                | 0            | 3                            | 3     |
|                                | 2            | 5                            | 7     |
| Times Measurement Used         | 38           | 151                          | 189   |
| Times Measurement Used (%)     | 19           | 77                           | 96    |

Measurements

[unpublished, non-peer-reviewed preprint]
Connection between JITAI mechanisms, symptoms, and measurements. Sankey-Diagram illustrating for which of the different JITAI mechanisms (state of vulnerability, proximal outcomes, distal outcomes, tailoring variables) we were able to match a depressive symptom (e.g. mood), and the measurements used to capture the changes (e.g. closed question). The JITAI mechanisms are displayed in blue, depressive symptoms in orange, green, and purple, and measurements in grey. The size of the rectangle indicates the number of times the mechanism, symptom, or measurement was found. The thickness of the connection indicates the number of times a measurement or symptom was used. Some measurements have been assigned to two or three JITAI mechanisms and double counting is therefore possible.
Multimedia Appendixes
Codebook for App Review.
URL: http://asset.jmir.pub/assets/033940f1998872fc7e53f6e2097bb0e7.docx