

Mental Health Mobile App Use to Manage Psychological Difficulties: An Umbrella Review

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Abstract

Purpose:

A rapid increase in global smartphone ownership and digital health technologies offers the potential for mobile phone applications to deliver mental health interventions. The purpose of this umbrella review was to bring together evidence reporting on mental health mobile applications to gain an understanding of the quality of current evidence, the positive and adverse effects of applications, and the mechanisms underlying such effects.

Design/methodology/approach:

A systematic search was carried out across six databases, for any systematic reviews or meta-analyses conducted up to 2020. Review quality was assessed using the Assessment of Multiple Systematic Reviews (AMSTAR 2).

Findings:

Across a total of 24 articles, a variety of clinical outcomes were assessed. Most compelling support was shown for applications targeting anxiety symptoms; some evidence favoured the use of applications for depression symptoms. Less evidence was available for the remaining clinical symptoms such as bipolar disorder, schizophrenia, post-traumatic stress disorder, sleep disorders, and substance use. Overall, there was limited evidence pertaining to adverse effects and change mechanisms, and a lack of quality reporting across a large proportion of included reviews. The included reviews demonstrate the need for further robust research before applications are recommended clinically.

Originality:

This umbrella review makes a valuable contribution to the current status of research and reviews investigating mental health mobile apps. Recommendations are made for improved adherence to review guidelines, to ensure risk of bias is minimised.

Key words: mHealth; mobile apps; mobile health; mental health; review

Introduction

The past decade has seen a rise in mobile health (mHealth) technologies used to deliver health interventions via short message service (SMS), Bluetooth, and mobile applications (apps) (World Health Organisation, 2011). The prospect of mHealth is enticing due to its potential to offer greater access to mental health interventions (Martin, 2012). Given the growth of digital health technologies, cognitive behavioural therapy (CBT) protocols have become computerized, offering promising digital self-guided interventions (Carlbring et al., 2017; Wong et al., 2018). Despite these successes, a review investigating a range of digital health interventions highlighted the heterogeneous nature of such interventions, thus making it difficult to draw consistent conclusions about their efficacy (Hollis et al., 2016). This would suggest that a narrower focus on specific interventions, such as mobile apps, may be appropriate to assess the efficacy of more homogeneous interventions.

In an investigation carried out across Western nations, 76% of surveyed individuals reported owning a smartphone (Taylor and Silver, 2019), highlighting opportunities for mHealth to reach large populations. Given that CBT self-help may be successfully adapted for computers (Carlbring et al., 2017; Wong et al., 2018), it is plausible that self-guided mobile app-interventions might also offer promise for mental health symptomatology. However, whilst it is estimated that upwards of 10,000 apps are available for targeting mental health difficulties, only a small proportion of these have undergone empirical investigation, and others do not adhere to evidence-based guidelines (Torous and Roberts, 2017). The current availability of new apps within the public domain is rapidly surpassing the rate at which their efficacy can be assessed with high quality research. Whilst randomized controlled trials (RCTs) are considered the gold standard for evaluating intervention effectiveness, well-designed RCTs require several years to complete several phases of investigation (Campbell et al., 2007; Watson, 2006), which is not proportional to the rate at which apps may be developed (Lee et al., 2004).

As well as establishing the efficacy and/or effectiveness of apps, the underlying change processes should be understood, both to identify relevant theory and to enhance the likelihood of developing effective app-interventions (Craig et al., 2013). At present, research has identified a variety of important common variables for promoting positive change in face-to-face psychotherapeutic interventions (Wampold, 2015), including empathy (Elliott et al., 2011), therapeutic alliance (Malin and Pos, 2014; Wong and Pos, 2012), and experiential emotion (Herrmann et al., 2014). Similar factors may be evident

amongst digital interventions; for example, within computerized CBT interventions, a virtual, meaningful relationship, comprising of trust and personalization has been considered to promote change (Purves and Dutton, 2013). The role of therapeutic alliance has also been queried within mobile interventions; however, there is currently a lack of robust research to draw firm conclusions about this variable (Henson et al., 2019).

Theory-informed process variables may also be common across both face-to-face and digital formats of intervention. For example, research into self-guided acceptance and commitment therapy (ACT) interventions suggests that psychological flexibility may serve to mediate reductions in depression and anxiety symptoms (French et al., 2017). Additionally, an investigation of both CBT-based and problem-solving based self-guided interventions for depression has shown mediation via common variables, despite different theoretical orientations; variables include reductions in dysfunctional attitudes, worry, and negative problem orientation, as well as increased perceived control (Warmerdam et al., 2010). It may therefore be expected that mobile interventions also promote change through similar processes. Given the differences between face-to-face and mHealth therapies, it is unclear whether common processes underlie change. The addition of human support and engagement reminders have demonstrated some moderating effects on the relationship between computerized interventions and depression symptoms (Cowpertwait and Clarke, 2013). It has also been suggested that internal factors (e.g., motivation and self-efficacy), as well as external factors (e.g., social support) may serve as additional factors resulting in preferable outcomes of app-use (Fitzgerald and McClelland, 2016). Despite these suggestions, systematic synthesis and appraisal of the evidence pertaining to mechanisms has yet to be carried out.

The efficacy of mental health mobile apps is a growing area of evidence, and whilst the development of apps is surpassing the scope for empirical support, many reviews currently exist in this field. As self-help is a prominent feature of the stepped-care models both in the UK and US (National Institute for Health and Care Excellence, 2011; Scogin et al., 2003), mobile apps may offer an accessible alternative to low-intensity interventions; however, the evidence base supporting these interventions must also be scrutinized, to offer new insights to the existing literature and identify gaps in knowledge. The purpose of this umbrella review is to bring together the evidence pertaining to interventional mobile apps, across samples varying in ages and clinical presentations, to investigate (a) the quality of systematic reviews

reporting on mental health app-interventions, (b) positive clinical effects of app-interventions, (c) adverse effects of app-interventions, and (d) reported mechanisms of change underlying these effects.

Method

Search Strategy

A systematic search was conducted in August 2020 across six databases: CINAHL, Embase, Medline, PsycINFO, ProQuest Dissertations & Theses Global, and Web of Science. To retrieve relevant articles, three overarching search term concepts were used to conduct searches: systematic review (e.g., “systematic literature review”), mobile applications (e.g., “mHealth”), and psychological outcomes (e.g., “mental illness*”). Searches were conducted on title, abstract, and keywords with truncations on standardised terms. Additionally, Medical Subject Headings (MeSH) terms and controlled vocabulary terms, such as PsycINFO Thesaurus were utilised. The full search strategy was agreed by all three authors (available upon request), and searches were carried out by one author (KB). No further limits, such as publication year were set, given the contemporary nature of the topic. Supplementary searches were conducted by checking reference lists and searching four relevant peer-reviewed journals (Journal of Medical Internet Research, JMIR mHealth and uHealth, Cyberpsychology, Behavior, and Social Networking, and npj Digital Medicine).

Selection Criteria and Screening

A set of criteria were established *a priori*, to facilitate systematic selection of articles. Only systematic literature reviews, including meta-analyses were included. Articles required a focus on the effects of mental health or wellbeing mobile applications. Participants of all ages and clinical presentations were included. Due to unavailability of translation, only articles in English were considered.

Reviews were excluded if reporting exclusively on alternative technologies (e.g., electronic monitoring, SMS, computerized self-help) or applications intended for physical health. Amongst reviews including an assortment of interventions, articles without separate analyses for mental health app-interventions were excluded. Articles were also excluded if solely reporting on user-experience or app-development.

All search results were imported to EndNote for duplicate removal and screening. Articles were first screened by titles, followed by abstracts, by one author (KB), in line with the selection criteria. Full text

screens were next conducted by one author (KB). When full texts could not be found, authors were contacted to request the full text or relevant information from the review.

Data Extraction and Data Synthesis

Data were extracted by one author (KB) and were only extracted if relevant to the aims stated in this umbrella review. Data were extracted utilising a data extraction form, designed by all three authors. The following data were extracted: journal, publication year, review type, databases searched, number of studies, number of participants, study designs, sample characteristics, interventions, and method of analysis. In some cases, primary sources were examined to extract data missing from reviews, including study design and information pertaining to the interventions. Following this, the data were synthesised into a systematic narrative review. Given the scope of umbrella reviews to summarise the evidence, the synthesised findings pertaining to clinical outcomes were reported from the included reviews. Due to the heterogeneity of the included reviews, in terms of clinical outcomes, methodological approaches, and instruments utilised within the reviews and primary studies, a meta-analysis of the data was impracticable.

Quality Assessment

The quality of articles was assessed after study selection and was not used as exclusion criteria (Smith et al., 2011). The developed Assessment of Multiple Systematic Reviews (AMSTAR 2) checklist was used, consisting of 16-items assessing search strategy, study selection, data extraction, and risk of bias (Shea et al., 2017). Whilst the former 11-item AMSTAR checklist demonstrates good reliability and construct validity for systematic reviews of randomized studies (Shea et al., 2009), the AMSTAR 2 enables assessment of those reporting on the intervention effects of non-randomized studies, as additional biases may be present within such designs (Egger et al., 1998; Pieper et al., 2018). Quality assessments were carried out by all authors independently and any disagreements were resolved through discussion.

All systematic reviews were rated according to the number of weaknesses they presented: high (no or one non-critical weakness), moderate (more than one non-critical weakness), low (one critical flaw), or critically low (more than one critical flaw) (Shea et al., 2017). These categorizations enabled assessments of overall confidence in the results of each publication, as well as enabling comparisons to be drawn between articles. Heterogeneity within each meta-analysis was also appraised by

inspecting the reported I^2 statistics; values exceeding 50% were considered to display large heterogeneity (Higgins and Thompson, 2002).

Results

Search Results

The initial search identified a total of 1,327 articles (Figure 1); following a title screen, 260 articles were considered potentially relevant, and their abstracts were screened to evaluate their eligibility. Of 141 reviews, a final 24 were included (see Appendix A for excluded studies).

Of the 24 included articles, seven were meta-analyses (Firth et al., 2017a; Firth et al., 2017b; Goreis et al., 2020; Ilagan et al., 2020; Linardon, 2020; Linardon et al., 2019; Weisel et al., 2019) and the remaining 17 were systematic literature reviews (Batra et al., 2017; Camacho et al., 2019; Donker et al., 2013; Dubad et al., 2017; Gould et al., 2019; Grist et al., 2017; Kerst et al., 2019; Lui et al., 2017; Melia et al., 2020; Menon et al., 2017; Pudukollu and Marques, 2019; Rathbone and Prescott, 2017; Rathbone et al., 2017; Shin et al., 2017; Wang et al., 2018; Wickersham et al., 2019; Zhao et al., 2017; Appendix B). There was overlap between reviews, with 57 relevant articles included in more than one review (Appendix C). Thus, the 24 reviews contained approximately 138 discrete studies exploring outcomes associated with mental health apps. Long-term outcomes (12-months) were reported by three reviews (Batra et al., 2017; Lui et al., 2017; Wickersham et al., 2019), each including one primary study assessing long-term effects. The total number of participants ranged from 227 (Donker et al., 2013) to 110,051 (Dubad et al., 2017) and ages ranged between 9-years (Grist et al., 2017) and 82-years (Shin et al., 2017); however, not all were included in analyses.

[Figure 1]

Quality Assessment

Using the AMSTAR 2 checklist, one of the reviews was rated 'high'; 14 reviews were rated as 'moderate', two were rated 'low', and the remaining seven produced 'critically low' ratings (Table I). A strength across reviews was the inclusion of PICO (population, intervention, comparison, outcome) components within research questions, as well as adequately detailing the studies.

Whilst many reviews listed reasons for excluding articles, none provided a comprehensive list of excluded studies. The reviews were also largely unable to fulfil requirements for a well-developed protocol, as all but four reviews (Linardon et al., 2019; Melia et al., 2020; Weisel et al., 2019; Wickersham et al., 2019) lacked reference to a registered protocol. Ten lacked an explicit plan for assessing risk of bias (Batra et al., 2017; Camacho et al., 2019; Gould et al., 2019; Grist et al., 2017; Kerst et al., 2019; Lui et al., 2017; Menon et al., 2017; Shin et al., 2017; Wang et al., 2018; Zhao et al., 2017); three of these, whilst discussing the quality of included papers, made no reference to validated quality assessment tools (Camacho et al., 2019; Grist et al., 2017; Shin et al., 2017). A final area of potential bias pertains to the limited search strategies, including lack of grey literature or reference list searches.

Across all meta-analyses, risk of bias analyses were evident, and all but one (Melia et al., 2020) demonstrated sufficient investigations of publication bias. Two meta-analyses reported potential publication bias (Linardon, 2020; Linardon et al., 2019), and significant heterogeneity was reported by five meta-analyses (Firth et al., 2017a; Ilagan et al., 2020; Linardon, 2020; Linardon et al., 2019; Weisel et al., 2019) one publication reported an I^2 statistic just below significant heterogeneity ($I^2 = 49.6\%$) (Firth et al., 2017b).

[Table I]

Clinical Outcomes

A broad range of apps were included across the reviews considered here. Table II demonstrates the most cited apps across the included reviews, according to clinical presentation. A greater range of apps were available to target depressive symptoms compared with other clinical presentations. It is noted that those apps receiving a greater number of citations may be due to greater number of primary studies investigating the intervention but is also likely to be due to the overlap between studies included within the reviews considered within this umbrella review (please see Appendix C).

Anxiety

Twelve reviews identified studies assessing anxiety and stress (Donker et al., 2013; Dubad et al., 2017; Firth et al., 2017b; Grist et al., 2017; Linardon et al., 2019; Lui et al., 2017; Menon et al., 2017; Punukollu and Marques, 2019; Rathbone and Prescott, 2017; Rathbone et al., 2017; Wang et al., 2018; Weisel et

al., 2019); eight found promising effects of several mental health apps, underpinned by various theoretical models (Donker et al., 2013; Firth et al., 2017b; Linardon et al., 2019; Lui et al., 2017; Menon et al., 2017; Rathbone and Prescott, 2017; Rathbone et al., 2017; Wang et al., 2018). Positive effects were reported, including significant reductions in stress and anxiety (state and trait), as well as improvements in active coping skills, relaxation, and allocation of attention (Donker et al., 2013; Lui et al., 2017; Menon et al., 2017; Rathbone and Prescott, 2017; Rathbone et al., 2017; Wang et al., 2018). These effects were noted both within-group, and between-group when compared with wait-list controls. No negative effects were reported across these reviews.

Two meta-analyses reported favourable effects of app-interventions on anxiety (Firth et al., 2017b; Linardon et al., 2019). Firth et al. (2017b) reported moderate effect sizes of apps on anxiety compared with inactive wait-list condition, with moderate heterogeneity. They also reported small effects when compared to active controls, with no heterogeneity. Linardon et al. (2019) reported efficacy of app-interventions for both social anxiety and panic symptoms with no heterogeneity, when analysing low risk of bias studies. They also found apps to be effective for generalized anxiety symptoms compared with controls when adjusting for publication bias. Conversely, Weisel et al. (2019) reported no significant differences between app and control conditions and reported high heterogeneity ($I^2 = 75\%$).

Four additional publications (Dubad et al., 2017; Grist et al., 2017; Pudukollu and Marques, 2019; Weisel et al., 2019) were unable to suggest efficacy or effectiveness of apps. Three of such reviews (Dubad et al., 2017; Grist et al., 2017; Pudukollu and Marques, 2019) reported on an investigation of the app 'Mobilettype' amongst adolescents, which demonstrated no effects on anxiety or stress, suggesting a lack of evidence supporting apps for adolescent anxiety.

Depression

Eighteen reviews, including many overlapping studies, reported on depression outcomes (Batra et al., 2017; Donker et al., 2013; Dubad et al., 2017; Firth et al., 2017a; Firth et al., 2017b; Gould et al., 2019; Grist et al., 2017; Ilagan et al., 2020; Kerst et al., 2019; Linardon, 2020; Linardon et al., 2019; Lui et al., 2017; Melia et al., 2020; Menon et al., 2017; Pudukollu and Marques, 2019; Rathbone and Prescott, 2017; Rathbone et al., 2017; Weisel et al., 2019; Zhao et al., 2017). Reviews reported favourable results for apps targeting depression, with small to large effects. Eight of the reviews found overall positive effects of apps (reductions in symptoms and increased positivity), with no report of negative effects

(Batra et al., 2017; Gould et al., 2019; Kerst et al., 2019; Lui et al., 2017; Menon et al., 2017; Rathbone and Prescott, 2017; Rathbone et al., 2017; Zhao et al., 2017).

Five meta-analyses reviewed the impact of apps on depression symptoms (Firth et al., 2017a; Ilagan et al., 2020; Linardon, 2020; Linardon et al., 2019; Weisel et al., 2019). Firth et al.'s (2017a) subgroup analyses showed a moderate effect of apps compared with inactive controls, yet high heterogeneity was reported ($I^2 = 65.6\%$). A small effect of apps was reported compared with active controls, with moderate heterogeneity ($I^2 = 47.2\%$). Three additional meta-analyses reported small to moderate effects of app-interventions compared with control conditions (Linardon, 2020; Linardon et al., 2019; Weisel et al., 2019), yet reported high heterogeneity ($I^2 = 54\%–75\%$). When adjusting for publication bias, two of these meta-analyses reported significant effects of apps compared with control conditions (Linardon, 2020; Linardon et al., 2019).

Mixed effects of apps were found by four reviews, which reported on several publications investigating the app 'Mobiletype' amongst adolescents (Donker et al., 2013; Dubad et al., 2017; Grist et al., 2017; Pudukollu and Marques, 2019). Results suggested that a negative association between app-use and symptoms was mediated by increased emotional self-awareness, rather than directly improving symptoms.

Apps did not significantly improve depression symptoms amongst those diagnosed with borderline personality disorder (Ilagan et al., 2020), and while associated with reductions in self-harm, apps were not effective in reducing suicidal ideation (Melia et al., 2020).

Bipolar Disorder

Four reviews considered the effects of apps on symptoms of bipolar disorder. Two of which, following a narrative synthesis, reported that apps offering mood monitoring and self-management advice are effective in alleviating bipolar symptoms, particularly depression symptoms (Lui et al., 2017; Menon et al., 2017). A meta-analysis by Firth et al. (2017a) identified two studies involving participants with bipolar disorder; their subgroup analysis found no significant differences between app-users and controls.

Psychosis

Three reviews reported on the same investigation of the app 'FOCUS', demonstrating efficacy amongst 33 individuals with schizophrenia (Batra et al., 2017; Lui et al., 2017; Menon et al., 2017). Results

showed significant reduction in positive symptoms and depressive symptoms (Ben-Zeev et al., 2014); however, none of these reviews assessed study quality. A fourth review identified three additional studies which each suggested benefits of social and peer support within apps, leading to improvements in hope, connectedness, and life satisfaction (Camacho et al., 2019).

Post-Traumatic Stress Disorder

Five systematic reviews (Gould et al., 2019; Lui et al., 2017; Rathbone et al., 2017; Wickersham et al., 2019; Zhao et al., 2017) and three meta-analyses (Goreis et al., 2020; Linardon et al., 2019; Weisel et al., 2019) considered the effects of apps on post-traumatic stress disorder (PTSD) symptoms. Due to overlap across the reviews, the results from a total of eight studies were synthesised.

Three reviews reporting on studies of the app 'PTSD Coach', suggested that apps for PTSD demonstrate potential (Gould et al., 2019; Goreis et al., 2020; Wang et al., 2018). Two of these reviews concluded that 'PTSD Coach' demonstrated small to moderate effects, improving PTSD symptoms from pre- to post-intervention (Gould et al., 2019; Goreis et al., 2020). Despite this, one such study also reported no significant differences between app and wait-list control conditions (Goreis et al., 2020). Wang et al. (2018) found qualitative feedback regarding this app, highlighting subjective reductions in PTSD symptoms. These reviews concluded that apps, such as 'PTSD Coach', demonstrate potential to reduce PTSD symptoms.

The remaining reviews suggested that primary results should be interpreted cautiously. Despite referencing the same studies supporting 'PTSD Coach', Lui et al. (2017) commented on the lack of transparency around the management of confidentiality. Additionally, two meta-analyses, including the outcomes of 'PTSD Coach' studies, reported no significant effects of apps on PTSD symptoms (Linardon et al., 2019; Weisel et al., 2019). Rathbone et al.'s (2017) review highlighted the lack of significant difference between the intervention and wait-list control conditions at follow-up and warned of the importance of further investigation, particularly to investigate long-term effects. Wickersham et al. (2019), while finding support for PTSD-focused apps in reducing symptoms with small-to-moderate effects, considered the inadequate statistical power and unclear risk of bias within the included studies. They also suggested that rebounding effects of PTSD symptoms may be evident at follow-up, concluding that the current evidence supporting apps is weak.

Sleep Disorders

One meta-analysis identified two RCTs assessing the efficacy of apps on sleep-related problems (Weisel et al., 2019). Due to the limited number of comparisons, data was not pooled; instead, the authors reported that two studies demonstrated significant reductions in sleep problems with medium to large effects. Three systematic reviews identified studies of apps to treat and monitor sleep-related difficulties (Rathbone et al., 2017; Shin et al., 2017; Wang et al., 2018). Within Shin et al.'s (2017) review, CBT for insomnia (CBT-I) apps demonstrated improvements in sleep, which were assessed using both subjective Likert scales and validated measures; despite this, differences did not consistently demonstrate statistical significance. The review suggested this may be due to a small sample size of 22 participants across three studies. They also found that apps focusing on sleep hygiene demonstrate positive effects, suggesting that the evidence favours the capability and efficacy of apps.

Two reviews focusing on sleep outcomes, amongst various other clinical presentations, also reported promising results. Rathbone et al. (2017) identified one RCT demonstrating significant reductions following CBT-I compared with the wait-list control condition. Wang et al. (2018) also found positive effects of a sleep-hygiene app, describing significant improvements in sleep quality and fatigue amongst pilots.

Substance Use

Outcomes relating to substance use were identified by five systematic reviews (Donker et al., 2013; Ilagan et al., 2020; Lui et al., 2017; Menon et al., 2017; Wang et al., 2018) and one meta-analysis (Weisel et al., 2019). Ten publications were identified by Lui et al. (2017), the majority of which demonstrated positive outcomes following app-use. They found evidence supporting the efficacy of one app ('LMBI-A'), whilst app-users showed significantly reduced drinking, and significantly more abstinence. The review by Wang et al. (2018) also identified support for this app from semi-structured interviews, which suggested reductions in alcohol use.

Both Lui et al. (2017) and Menon et al. (2017) identified the same study outlining evidence for the app 'A-CHESS', based on self-determination principles. Compared to control conditions those using the app reported significantly fewer heavy drinking days post-intervention and 12-months later.

Lui et al. (2017) also identified further evidence for two mobile apps in reducing smoking: 'SmartQuit' and 'Mobile Contingency Management'; the former of these was underpinned by ACT principles, and

the latter by behaviourism principles. The review found that studies supported both apps in increasing rates of quitting smoking, with 'SmartQuit' users demonstrating greater acceptance of cravings compared with active controls.

Three reviews identified favourable evidence of the app 'DBT Coach', amongst individuals diagnosed with borderline personality disorder (Donker et al., 2013; Ilagan et al., 2020; Lui et al., 2017); app-use resulted in significantly reduced emotional intensity with medium effects and urge to use substances with small effects (Rizvi et al., 2011).

Compared with Lui et al. (2017), Wang et al.'s (2018) review reported less efficacy; the only RCT identified by this review investigated the app 'Party Planner' which was not successful in reducing alcohol consumption. Additionally, Weisel et al.'s (2019) meta-analysis suggested significant effects of apps in reducing smoking compared with controls, but not in reducing alcohol consumption. The reviews therefore highlight a mix of evidence both supporting and challenging the efficacy of apps for substance use; there was also a lack of quality assessment amongst many of these reviews.

[Table II]

Change Mechanisms

None of the included reviews aimed to assess mechanisms of change; however, several reviews synthesised evidence highlighting potential mediation effects. Four reviews reported that the app 'Mobiletype' did not demonstrate direct effects on depressive symptoms amongst young people (Donker et al., 2013; Dubad et al., 2017; Grist et al., 2017; Punukollu and Marques, 2019). Instead, an indirect association was found, mediated by increased emotional self-awareness, consistent with qualitative feedback reported within two reviews suggesting that mood-monitoring apps enhance self-awareness and self-reflection (Dubad et al., 2017; Punukollu and Marques, 2019).

An additional suggestion was made by two meta-analyses, which both reported significantly smaller effect sizes of app-use when compared to active control conditions rather than to wait-list conditions (Firth et al., 2017a; 2017b). The authors of these meta-analyses, as well as Lui et al. (2017) considered that expectancy effects, rather than psychotherapeutic mechanisms, may contribute to observed change. They recommended that future research pays attention to the processes promoting change.

Discussion

Clinical Outcomes

Overall, many positive effects were reported across the reviews, particularly on anxiety and depression outcomes. Across six systematic reviews and two meta-analyses, a convincing body of evidence was presented favouring apps for anxiety. Many apps were based on CBT principles, and assessed amongst adult samples. Evidence was not found to support app-efficacy for anxiety amongst younger samples (Grist et al., 2017; Pudukollu and Marques, 2019); however, this may be due to a dearth of research recruiting this demographic.

Research supporting the positive effects of apps on depression appeared compelling across half of the included articles in this review. Reviews reporting on the outcomes of individuals with bipolar disorder and schizophrenia also demonstrated improvements in depression symptoms (Batra et al., 2017; Firth et al., 2017a; Lui et al., 2017; Menon et al., 2017). However, the evidence to suggest a direct effect of app-use on improvements in depression was mixed, with some suggesting there is currently insufficient evidence to indicate direct benefits of apps (Donker et al., 2013; Dubad et al., 2017; Grist et al., 2017). Significant heterogeneity was also evident within the meta-analyses (Firth et al., 2017a; Linardon, 2020; Linardon et al., 2019; Weisel et al., 2019); thus, the research favouring apps for treating depression symptoms is less cogent, as compared with the anxiety literature.

The research available for other clinical symptoms generally demonstrated positive effects yet relied on a smaller body of primary studies. Many of the reviews reported on the same publications, and concluded that apps currently demonstrate potential, nevertheless require further scrutiny. Whilst apps may give rise to improvements in sleep, substance use, and PTSD symptoms, further questions are raised regarding issues of confidentiality (Lui et al., 2017), research quality (Rathbone et al., 2017; Wickersham et al., 2019), comparisons with alternative internet-delivered interventions (Goreis et al., 2020; Weisel et al., 2019), and long-term efficacy (Wickersham et al., 2019).

This umbrella review also aimed to investigate the adverse effects of app-interventions; however, none of the articles reported iatrogenic effects. Two reviews discussed possible adverse effects, including increased focus on negative thoughts, emotions, and urges, leading to symptom persistence (Dubad et al., 2017; Lui et al., 2017). This is consistent with the proposal that increased perseverative thinking may maintain symptoms (Clancy et al., 2016; Sorg et al., 2012). However, despite the negative impact

of preservative cognition, constructive repetitive thought, such as self-reflection, may be beneficial (Watkins, 2008). Therefore, there remains a lack of cogent evidence reporting on iatrogenic effects of app-use.

Mechanisms of Change

Another aim of this review was to identify the reported mechanisms of change; however, these were not directly investigated by the included articles. Nonetheless, emotional self-awareness was suggested to give rise to improvements in depression symptoms (Donker et al., 2013; Dubad et al., 2017; Punukollu and Marques, 2019). This suggestion may be plausible, given the reported association between poor emotional self-awareness and symptoms of depression and anxiety amongst young people (Kranzler et al., 2015; Suveg et al., 2008). An investigation amongst adults also found emotional self-awareness to mediate the relationship between app engagement and changes in depression and anxiety symptoms; however, this was found for only those with baseline clinical levels (Bakker and Rickard, 2018). Further research is thus required to understand the role of emotional self-awareness amongst non-clinical samples, and to clarify whether this concept serves merely as a mediator, or a mechanism of change.

Expectancy or placebo effects were considered in explaining some of the reported changes (Firth et al., 2017a; 2017b). Within two meta-analyses, effect sizes were smaller when comparing interventions with active, rather than wait-list control conditions, suggesting change may not be underpinned by psychotherapeutic elements of interventions. However, it is difficult to estimate the size and efficacy of potential expectancy effects due to the lack of methodologically robust research (Torous and Firth, 2016); thus, such effects are yet to be understood. Given the risk of bias associated with poor allocation concealment within RCTs (Gellatly et al., 2007; Schulz, 1995), more attention should be paid to ensure the quality of studies.

Review Quality

As highlighted by the quality appraisal, 10 reviews lacked risk of bias assessments, diminishing the confidence in these reviews. It has been stated elsewhere that systematic reviews do not consistently adhere to guidelines or make use of quality assessment tools (Pussegoda et al., 2017). The absence of risk of bias assessments may lead to over- or under-estimations of effects (Higgins et al., 2011). Many of the included reviews reporting on PTSD outcomes referred to the same primary sources, yet

drew different conclusions about the efficacy of apps, with some stating that apps demonstrate small-to-moderate effects (Goreis et al., 2020; Gould et al., 2019; Wang et al., 2018), and other reviews challenging the efficacy following a quality assessment (Rathbone et al., 2017; Wickersham et al., 2019). Thus, this umbrella review highlights the need for more consistency and adherence to guidelines.

Future Research

Several research needs were highlighted across the reviews; the first of which was for more rigorous and robust investigations of efficacy, which may be possible with RCTs. Additionally, research investigating the longevity of effects was recommended, as effects have yet to demonstrate long-term efficacy (Batra et al., 2017; Menon et al., 2017; Rathbone et al., 2017; Wickersham et al., 2019). Whilst these investigations would enable validation of apps, and potentially highlight iatrogenic effects, they would not demonstrate the processes fundamental to change (Torous and Firth, 2016). Whilst mechanisms may be investigated within RCTs via mediational analyses (Kraemer et al., 2002), it should be noted that mediation does not equate to mechanism (Nock, 2007). Thus, designs such as single-case experimental designs might also benefit our understanding of mechanisms (Dallery et al., 2013; Kazdin, 2007). This review also highlights the lack of evidence supporting app-use amongst younger individuals, a finding consistent across digital health interventions (Hollis et al., 2016). To better assess the efficacy of apps for young people, it is important that high quality research designs are implemented, with consideration of user-preferences and potential disadvantages of app-use (Grist et al., 2018).

Limitations

An umbrella review was chosen due to the breadth of reviews currently addressing a range of mental health apps. However, the quality of the data presented here is determined by the quality of both included reviews, and the primary studies. Nevertheless, this review has endeavoured to highlight the quality of systematic literature reviews within the field, as a result, demonstrating the need for better adherence to guidelines.

Given the aims of this review, the data synthesised only concerned clinical outcomes. Furthermore, other data reported across the included reviews is likely to be lost. Additionally, despite attempts to use various search terms and reference lists, it is possible that reviews may have been missed, given the breadth of samples and clinical presentations. Within this umbrella review, apps considered within the narrative review reflect those discussed by the included reviews; nonetheless, the effects of apps may

be overstated due to the magnitude of overlapping primary studies. Attempts were made to identify overlapping studies to minimise biases resulting from overstatement of effects. Despite this, it is difficult to account for all overlap across the reviews.

Conclusions

The current literature demonstrates the broad use of mobile apps to manage a range of mental health symptoms. This umbrella review highlights the positive effects of mental health apps for anxiety and depression amongst adult samples. Despite this, when considering the review quality and heterogeneity within the findings, the evidence in support of apps to address depression is less cogent. Furthermore, the effective use of apps to manage other psychological difficulties remains limited. Fewer reviews, referencing fewer primary studies, were identified to explore the use of apps to manage symptoms of bipolar disorder, psychosis, PTSD, sleep disorders, and substance use.

This umbrella review highlights the variable quality of reviews, with 10 of the 24 included reviews lacking a risk of bias assessment. It is therefore unsurprising that despite reporting on many of the same primary studies, divergent conclusions were drawn. To minimise bias, future reviews should interpret results in view of research quality. At present, little is known about potential adverse effects of app-use, longevity of effects, and mechanisms of change. Further research focusing on these factors might offer valuable insights for the development of efficacious apps.

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Table 1. Quality of Included Reviews using AMSTAR 2 Checklist

First Author, Date	(1) PICO	(2) Protocol	(3) Design	(4) Search	(5) Study selection	(6) Extraction	(7) Exclusion	(8) Included studies	(9) RoB	(10) Funding	(11) Combination	(12) Meta-analysis RoB	(13) RoB discussion	(14) Heterogeneity	(15) Publication bias	(16) Conflict of interest	Overall rating
Batra (2017)	Y	N	N	P	Y	N	N	Y	N	N	N/A	N/A	N	Y	N/A	Y	Critically Low
Camacho (2019)	Y	N	N	P	Y	N	N	P	N	N	N/A	N/A	N	N	N/A	Y	Critically Low
Donker (2013)	Y	N	N	Y	Y	Y	N	Y	Y	N	N/A	N/A	Y	Y	N/A	Y	Moderate
Dubad (2017)	Y	P	N	Y	Y	Y	N	Y	Y	N	N/A	N/A	Y	Y	N/A	N	Moderate
Firth (2017a)	Y	P	N	Y	Y	N	N	Y	Y	N	Y	Y	Y	Y	Y	N	Moderate
Firth (2017b)	Y	N	N	Y	Y	N	N	Y	Y	N	Y	Y	Y	Y	Y	N	Moderate
Gould (2019)	Y	N	Y	P	Y	Y	N	Y	N	N	N/A	N/A	N	Y	N/A	N	Critically Low
Goreis (2020)	Y	N	N	P	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Moderate
Grist (2017)	Y	N	Y	Y	N	N	N	Y	N	N	N/A	N/A	Y	Y	N/A	Y	Low
Ilagan (2020)	Y	N	Y	P	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	High
Kerst (2019)	Y	N	N	P	N	N	N	Y	N	N	N/A	N/A	Y	Y	N/A	Y	Moderate
Linardon (2019)	Y	Y	Y	P	Y	Y	N	P	Y	N	Y	Y	Y	Y	Y	N	Moderate
Linardon (2020)	Y	N	Y	P	N	N	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Moderate
Lui (2017)	Y	N	N	N	N	N	N	P	N	N	N/A	N/A	Y	Y	N/A	N	Critically low
Melia (2020)	Y	Y	Y	Y	Y	Y	N	Y	Y	N	N/A	N/A	Y	N	N/A	Y	Moderate
Menon (2017)	Y	N	N	P	Y	Y	N	P	N	N	N/A	N/A	N	Y	N/A	Y	Critically Low
Punukollu (2019)	Y	N	N	P	N	N	N	Y	Y	N	N/A	N/A	Y	N	N/A	Y	Moderate
Rathbone (2017)	Y	N	Y	P	Y	N	N	P	Y	N	N/A	N/A	Y	N	N/A	Y	Moderate
Rathbone, Prescott (2017)	Y	N	N	P	Y	N	N	P	Y	N	N/A	N/A	Y	Y	N/A	Y	Moderate
Shin (2017)	Y	N	N	P	Y	Y	N	Y	N	N	N/A	N/A	Y	Y	N/A	Y	Low
Wang (2018)	Y	N	Y	P	Y	N	N	Y	N	N	N/A	N/A	N	N	N/A	Y	Critically Low
Weisel (2019)	Y	Y	Y	P	Y	N	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Moderate
Wickersham (2019)	Y	Y	Y	P	Y	Y	N	Y	Y	N	N/A	N/A	Y	Y	N/A	Y	Moderate
Zhao (2017)	Y	N	N	P	Y	Y	N	Y	N	N	N/A	N/A	N	Y	N/A	Y	Critically Low
Total (n)	24	4	10	6	19	10	2	18	14	1	7	7	18	19	7	18	

Y: Yes; N: No; P: Partial yes; N/A: Not applicable

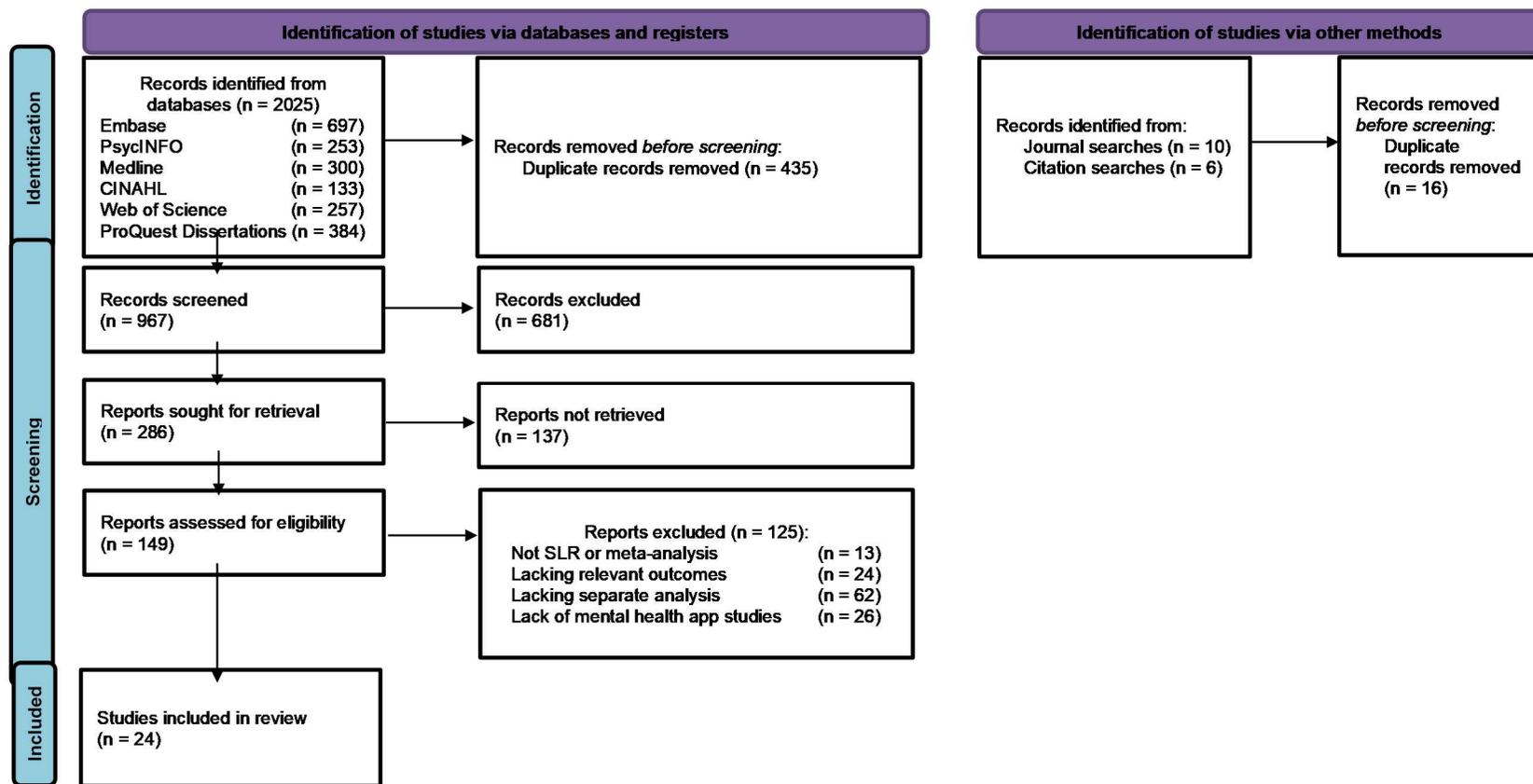


Figure 1. PRISMA 2020 flow diagram of search and selection of articles, adapted from Page et al. (2021)

Table II. Most Cited Apps according to Clinical Presentation

Clinical presentation	Apps (Primary Studies)	Intended use of technology	Theoretical/Therapeutic Model(s)	Reviews Citing Apps
Anxiety	<i>Flowy</i> (Pham et al., 2016)	Intervention: breathing retraining Self-monitoring	Self-determination theory	Firth et al. (2017b), Rathbone and Prescott (2017), Wang et al. (2018), Weisel et al. (2019)
	Cognitive Bias Modification App (Enock et al., 2014)	Intervention: attention bias modification training	Cognitive therapy	Firth et al. (2017b), Linardon et al. (2019), Lui et al. (2017)
	<i>Ångesthjälpen</i> (The Anxiety Help; Ivanova et al., 2016)	Intervention: behavioural and interactive exercises	ACT	Firth et al. (2017b), Linardon et al. (2019)
Depression	<i>Mobilitytype</i> (Reid et al., 2008)	Self-monitoring / self-assessment	Not stated by app developers	Donker et al. (2013), Dubad et al. (2017), Grist et al. (2017), Firth et al. (2017a), Menon et al. (2017), Linardon et al. (2019), Punukollu and Marques (2019), Rathbone and Prescott (2017)
	<i>Get Happy Program</i> (Watts et al., 2013)	Intervention: interactive activities	CBT	Batra et al. (2017), Donker et al. (2013), Firth et al. (2017a), Kerst et al. (2019), Lui et al. (2017), Menon et al. (2017), Rathbone and Prescott (2017), Zhao et al. (2017)
	Unnamed Behavioural Activation App (Ly et al., 2015)	Intervention: behavioural activation, blended with face-to-face sessions	CBT	Batra et al. (2017), Firth et al. (2017a), Kerst et al. (2019), Menon et al. (2017), Rathbone et al. (2017)
	<i>Project EVO</i> (Arean et al. 2016)	Intervention: activities to modulate cognitive control	Cognitive theory	Firth et al. (2017a), Kerst et al. (2019), Linardon et al. (2019), Rathbone and Prescott (2017), Weisel et al. (2019)
	<i>iPST</i> (Arean et al., 2016)	Intervention: goal setting and action planning	Problem Solving therapy	Firth et al. (2017a), Kerst et al. (2019), Linardon et al. (2019), Rathbone and Prescott (2017), Weisel et al. (2019)
Bipolar Disorder	<i>MONARCA</i> (Faurholt-Jepsen et al., 2015)	Self-monitoring / self-assessment	Not stated by app developers	Batra et al. (2017), Linardon et al. (2019)
	<i>SIMPL</i> e (Hidalgo-Mazzei et al., 2016)	Self-monitoring / self-assessment Intervention: psychoeducation	Transtheoretical model (Colom and Vieta, 2006)	Batra et al. (2017), Rathbone and Prescott (2017)

Psychosis	<i>FOCUS</i> (Ben-Zeev et al., 2013)	Self-monitoring / self-assessment Intervention: on-demand resources	CBT	Batra et al. (2017), Rathbone and Prescott (2017)
PTSD	<i>PTSD Coach</i> (Kuhn et al., 2014)	Intervention: psychoeducation, symptom management Self-assessment	CBT	Gould et al. (2019), Goreis et al. (2020), Linardon et al. (2019), Lui et al. (2017), Rathbone et al. (2017), Wang et al. (2018), Weisel et al. (2019), Wickersham et al. (2019)
	<i>T2 Mood Tracker</i> (Bush et al., 2014) <i>LifeArmor</i> (Roy et al., 2017)	Self-monitoring / self-assessment Intervention: psychoeducation Self-assessment	Not stated by app developers CBT, mindfulness	Gould et al. (2019), Wang et al. (2018) Goreis et al. (2020), Wickersham et al. (2019)
Sleep Disorders	<i>MORE Energy</i> (van Drongelen et al., 2014)	Intervention: advice tailored to users	Chronobiology	Shin et al. (2017), Wang et al. (2018)
	<i>Sleepcare</i> (Horsch et al., 2017)	Intervention: interactive module activities	CBT	Linardon et al. (2019), Weisel et al. (2019)
Substance Use	<i>DBT Coach</i> (Rizvi et al., 2011)	Intervention: psychoeducation, therapeutic skills Self-monitoring	DBT	Donker et al. (2013), Ilagan , Lui et al. (2017)
	<i>A-CHESS</i> (Gustafson et al., 2014)	Intervention: therapeutic skills Self-monitoring	Self-determination theory	Dubad et al. (2017), Lui et al. (2017)
	<i>SmartQuit</i> (Heffner et al., 2015)	Intervention: therapeutic skills Self-monitoring	ACT, CBT	Lui et al. (2017), Linardon (2020)
	<i>BASICS</i> (Witkiewitz et al., 2014)	Intervention: therapeutic skills Self-monitoring	Motivational interviewing, mindfulness	Lui et al. (2017), Weisel et al. (2019)
	<i>LMBI-A</i> (Dulin et al., 2014)	Intervention: psychoeducation, therapeutic skills Self-monitoring	CBT	Lui et al. (2017), Wang et al. (2018)

Notes:

CBT = Cognitive behavioural therapy

ACT = Acceptance and commitment therapy

DBT = Dialectical behaviour therapy

Appendix A – Excluded studies

Studies excluded from full text screen

First author, year	Title	Reason for exclusion
Aboujaoude, 2015	Telemental health: A status update	Not a systematic literature review or meta-analysis
Alvarez-Jimenez, 2014	Online, social media and mobile technologies for psychosis treatment: a systematic review on novel user-led interventions	Lack of mental health app studies
Alyami, 2017	Social anxiety apps: a systematic review and assessment of app descriptors across mobile store platforms	Lack of relevant outcomes
Anastasiadou, 2018	A systematic review of mHealth interventions for the support of eating disorders	Lack of separate analysis
Arshad, 2019	A Systematic Review of the Evidence Supporting Mobile- and Internet-Based Psychological Interventions For Self-Harm	Lack of separate analysis
Ashford, 2019	Systematic review: Digital recovery support services used to support substance use disorder recovery	Lack of separate analysis
Baker, 2018	Combatting social isolation and increasing social participation of older adults through the use of technology: A systematic review of existing evidence	Lack of mental health app studies
Bakker, 2016	Mental Health Smartphone Apps: Review and Evidence-Based Recommendations for Future Developments	Not a systematic literature review or meta-analysis
Barakat, 2019	Evaluating the role of digital intervention design in treatment outcomes and adherence to eTherapy programs for eating disorders: A systematic review and meta-analysis	Lack of separate analysis
Berry, 2016	Acceptability of Interventions Delivered Online and Through Mobile Phones for People Who Experience Severe Mental Health Problems: A Systematic Review	Lack of mental health app studies
Bonet, 2017	Use of mobile technologies in patients with psychosis: A systematic review	Lack of separate analysis
Byambasuren, 2018	Prescribable mHealth apps identified from an overview of systematic reviews	Not a systematic literature review or meta-analysis
Celik, 2019	The effect of technology-based programmes on changing health behaviours of adolescents: Systematic review	Lack of separate analysis
Champion, 2019	Effectiveness of school-based eHealth interventions to prevent multiple lifestyle risk behaviours among adolescents: a systematic review and meta-analysis	Lack of mental health app studies
Chan, 2019	Effects of Social Media and Mobile Health Apps on Pregnancy Care: Meta-Analysis	Lack of separate analysis
Changizi, 2017	Effectiveness of the mHealth technology in improvement of healthy behaviors in an elderly population-a systematic review	Lack of relevant outcomes
Chen, 2016	The Effect of Information Communication Technology Interventions on Reducing Social Isolation in the Elderly: A Systematic Review	Lack of separate analysis
Chen, 2020	Application of telehealth intervention in Parkinson's disease: A systematic review and meta-analysis	Lack of separate analysis

Cheng, 2020	Technology-Delivered Psychotherapeutic Interventions in Improving Depressive Symptoms Among People with HIV/AIDS: A Systematic Review and Meta-analysis of Randomised Controlled Trials	Lack of separate analysis
Chib, 2018	Theoretical advancements in mHealth: A systematic review of mobile app	Lack of separate analysis
Christopher, 2019	Mobile Health for Traumatic Brain Injury: A Systematic Review of the Literature and Mobile Application Market	Lack of relevant outcomes
Colombo, 2019	Current State and Future Directions of Technology-Based Ecological Momentary Assessment and Intervention for Major Depressive Disorder: A Systematic Review	Lack of separate analysis
Coorey, 2018	Effectiveness, acceptability and usefulness of mobile applications for cardiovascular disease self-management: Systematic review with meta-synthesis of quantitative and qualitative data	Lack of separate analysis
Costanzo, 2019	Diagnostic and interventional implications of telemedicine in Alzheimer's disease and mild cognitive impairment: A literature review	Lack of separate analysis
Cox, 2017	Psychosocial interventions for self-harm, suicidal ideation and suicide attempt in children and young people: What? How? Who? and Where?	Lack of mental health app studies
Cuijpers, 2017	Internet and mobile interventions for depression: Opportunities and challenges	Not a systematic literature review or meta-analysis
Daly, 2018	The Effect of Mobile App Interventions on Influencing Healthy Maternal Behavior and Improving Perinatal Health Outcomes: Systematic Review	Lack of relevant outcomes
de Korte, 2018	Behavior Change Techniques in mHealth Apps for the Mental and Physical Health of Employees: Systematic Assessment	Not a systematic literature review or meta-analysis
Dick, 2019	A systematic review of the effectiveness of digital interventions for illicit substance misuse harm reduction in third-level students	Lack of mental health app studies
Direito, 2017	mHealth technologies to influence physical activity and sedentary behaviors: Behavior change techniques, systematic review and meta-analysis of randomized controlled trials	Lack of relevant outcomes
Dogan, 2017	Smartphone-based monitoring of objective and subjective data in affective disorders: Where are we and where are we going? Systematic review	Lack of separate analysis
Dol, 2017	eHealth interventions for parents in neonatal intensive care units: a systematic review	Lack of separate analysis
Dol, 2020	Impact of Mobile Health Interventions During the Perinatal Period on Maternal Psychosocial Outcomes: A Systematic Review	Lack of separate analysis
Domhardt, 2019	Internet- and mobile-based interventions for anxiety disorders: A meta-analytic review of intervention components	Lack of mental health app studies
Domhardt, 2020	Internet- And Mobile-Based Interventions for Mental and Somatic Conditions in Children and Adolescents	Lack of separate analysis
Dyer, 2012	Mobile Applications and Internet-based Approaches for Supporting Non-professional Caregivers: A Systematic Review	Lack of separate analysis

Ebert, 2018	Internet- and Mobile-Based Psychological Interventions: Applications, Efficacy, and Potential for Improving Mental Health A Report of the EFPA E-Health Taskforce	Not a systematic literature review or meta-analysis
Ehrenreich, 2011	Are mobile phones and handheld computers being used to enhance delivery of psychiatric treatment? A systematic review	Lack of mental health app studies
Escriva Bouley, 2018	Increasing physical activity with mobile devices: a meta-analysis	Lack of relevant outcomes
Fanning, 2012	Increasing physical activity with mobile devices: a meta-analysis	Lack of relevant outcomes
Faurholt-Jepsen, 2016	Electronic self-monitoring of mood using IT platforms in adult patients with bipolar disorder: A systematic review of the validity and evidence	Lack of separate analysis
Faurholt-Jepsen, 2018	Electronic monitoring in bipolar disorder	Not a systematic literature review or meta-analysis
Fino, 2019	Monitoring healthy and disturbed sleep through smartphone applications: a review of experimental evidence	Lack of relevant outcomes
Firth, 2015	Smartphone Apps for Schizophrenia: A Systematic Review	Lack of relevant outcomes
Firth, 2016	Mobile Phone Ownership and Endorsement of "mHealth" Among People with Psychosis: A Meta-analysis of Cross-sectional Studies	Lack of relevant outcomes
Fleming, 2018	Beyond the trial: Systematic review of real-world uptake and engagement with digital self-help interventions for depression, low mood, or anxiety	Lack of relevant outcomes
Flujas-Contreras, 2019	Technology-based Parenting Interventions for Children's Physical and Psychological Health: A Systematic Review and Meta-Analysis	Lack of mental health app studies
Fowler, 2016	Mobile technology-based interventions for adult users of alcohol: A systematic review of the literature	Lack of separate analysis
Franco Martin, 2018	A Systematic Literature Review of Technologies for Suicidal Behavior Prevention	Lack of relevant outcomes
Getty, 2019	Mobile telephone-delivered contingency management interventions promoting behaviour change in individuals with substance use disorders: a meta-analysis	Lack of mental health app studies
Gindidis, 2018	A systematic scoping review of adolescent mental health treatment using mobile apps	Lack of relevant outcomes
Gire, 2017	mHealth based interventions for the assessment and treatment of psychotic disorders: a systematic review	Lack of separate analysis
Giroux, 2017	Online and mobile interventions for problem gambling, alcohol, and drugs: A systematic review	Lack of separate analysis
Gliddon, 2017	Online and mobile technologies for self-management in bipolar disorder: A systematic review	Lack of separate analysis
Grist, 2019	Technology Delivered Interventions for Depression and Anxiety in Children and Adolescents: A Systematic Review and Meta-analysis	Lack of mental health app studies
Harerimana, 2019	The Use of Technology for Mental Healthcare Delivery Among Older Adults With Depressive Symptoms: A Systematic Literature Review	Lack of separate analysis
Hernandez Silva, 2019	The effectiveness of mHealth for self-management in improving pain, psychological	Lack of separate analysis

	distress, fatigue, and sleep in cancer survivors: a systematic review	
Hollis, 2017	Annual Research Review: Digital health interventions for children and young people with mental health problems - a systematic and meta-review	Lack of separate analysis
Holmes, 2019	A systematic review of technology-assisted interventions for co-morbid depression and substance use	Lack of mental health app studies
Hutton, 2019	Mhealth interventions to reduce alcohol use in young people: A systematic review of the literature	Lack of separate analysis
Johnson, 2017	The Utilization of Technological Innovations to Support College Student Mental Health: Mobile Health Communication	Lack of relevant outcomes
Josephine, 2017	Internet- and mobile-based depression interventions for people with diagnosed depression: A systematic review and meta-analysis	Lack of separate analysis
Karasouli, 2014	Assessing the Evidence for e-Resources for Mental Health Self-Management: A Systematic Literature Review	Lack of separate analysis
Kazemi, 2017	A Systematic Review of the mHealth Interventions to Prevent Alcohol and Substance Abuse	Lack of separate analysis
Kiluk, 2019	Technology-Delivered Cognitive-Behavioral Interventions for Alcohol Use: A Meta-Analysis	Lack of separate analysis
Kim, 2020	Possible application of ecological momentary assessment to older adults' daily depressive mood: Integrative literature review	Lack of separate analysis
Kreuze, 2017	Technology-enhanced suicide prevention interventions: A systematic review	Lack of separate analysis
Kruse, 2020	Measures of Effectiveness, Efficiency, and Quality of Telemedicine in the Management of Alcohol Abuse, Addiction, and Rehabilitation: Systematic Review	Lack of separate analysis
Lapointe, 2020	Impact of telemedicine on diagnosis, clinical management and outcomes in rural trauma patients: A rapid review	Lack of mental health app studies
Larsen, 2016	A Systematic Assessment of Smartphone Tools for Suicide Prevention	Not a systematic literature review or meta-analysis
Lattie, 2019	Digital Mental Health Interventions for Depression, Anxiety, and Enhancement of Psychological Well-Being Among College Students: Systematic Review	Lack of separate analysis
Lau, 2020	Android and iPhone Mobile Apps for Psychosocial Wellness and Stress Management: Systematic Search in App Stores and Literature Review	Lack of relevant outcomes
Lawes-Wickwar, 2018	Application and Effectiveness of Telehealth to Support Severe Mental Illness Management: Systematic Review	Lack of separate analysis
Lindheim, 2015	Mobile technology boosts the effectiveness of psychotherapy and behavioral interventions: A meta-analysis	Lack of separate analysis
Loo Gee, 2016	Effectiveness of mobile technologies delivering Ecological Momentary Interventions for stress and anxiety: a systematic review	Lack of separate analysis
Lopez-Rodriguez, 2020	New Technologies to Improve Pain, Anxiety and Depression in Children and Adolescents with Cancer: A Systematic Review	Lack of separate analysis

Loucas, 2014	E-therapy in the treatment and prevention of eating disorders: A systematic review and meta-analysis	Lack of mental health app studies
Lunde, 2018	The Effectiveness of Smartphone Apps for Lifestyle Improvement in Noncommunicable Diseases: Systematic Review and Meta-Analyses	Lack of separate analysis
Lyzwinski, 2018	A systematic review of electronic mindfulness-based therapeutic interventions for weight, weight-related behaviors, and psychological stress	Lack of separate analysis
McCall, 2019	The Use of Culturally-Tailored Telehealth Interventions in Managing Anxiety and Depression in African American Adults: A Systematic Review	Lack of mental health app studies
McColl, 2014	Peer support intervention through mobile application: An integrative literature review and future directions	Lack of mental health app studies
McKay, 2018	Evaluating mobile phone applications for health behaviour change: A systematic review	Lack of relevant outcomes
Mikolasek, 2018	Effectiveness of Mindfulness- and Relaxation-Based eHealth Interventions for Patients with Medical Conditions: A Systematic Review and Synthesis	Lack of mental health app studies
Milne-Ives, 2020	Mobile Apps for Health Behavior Change in Physical Activity, Diet, Drug and Alcohol Use, and Mental Health: Systematic Review	Lack of separate analysis
Miralles, 2020	Smartphone Apps for the Treatment of Mental Disorders: Systematic Review	Lack of relevant outcomes
Montagni, 2019	Mental Health-Related Digital Use by University Students: A Systematic Review	Lack of mental health app studies
Nair, 2018	The effectiveness of telemedicine interventions to address maternal depression: A systematic review and meta-analysis	Lack of separate analysis
Namil, 2016	Unlocking smartphone potential in health care by providing smartphones to patients: A systematic review	Lack of separate analysis
Naslund, 2017	Digital technology for treating and preventing mental disorders in low-income and middle-income countries: A narrative review of the literature	Not a systematic literature review or meta-analysis
Nesvåg, 2018	Feasibility and Effects of Digital Interventions to Support People in Recovery from Substance Use Disorders: Systematic Review	Lack of separate analysis
Ng, 2019	User Engagement in Mental Health Apps: A Review of Measurement, Reporting, and Validity	Lack of relevant outcomes
Park, 2019	Smartphone applications for the treatment of depressive symptoms: A meta-analysis and qualitative review	Lack of relevant outcomes
Păsărelu, 2020	Attention-deficit/ hyperactivity disorder mobile apps: A systematic review	Lack of relevant outcomes
Payne, 2015	Behavioral Functionality of Mobile Apps in Health Interventions: A Systematic Review of the Literature	Lack of separate analysis
Perle, 2013	How psychological telehealth can alleviate society's mental health burden: A literature review	Not a systematic literature review or meta-analysis
Perski, 2017	Conceptualising engagement with digital behaviour change interventions: A systematic review using principles from critical interpretive synthesis	Lack of relevant outcomes

Pospos, 2018	Web-Based Tools and Mobile Applications to Mitigate Burnout, Depression, and Suicidality Among Healthcare Students and Professionals: A Systematic Review	Lack of separate analysis
Qan'ir, 2019	Systematic Review of Technology-Based Interventions to Improve Anxiety, Depression, and Health Related Quality of Life Among Patients with Prostate Cancer	Lack of separate analysis
Ramsey, 2019	Technology-Based Alcohol Interventions in Primary Care: Systematic Review	Lack of separate analysis
Rantala, 2020	The effectiveness of web-based mobile health interventions in paediatric outpatient surgery: A systematic review and meta-analysis of randomized controlled trials	Lack of separate analysis
Rodriguez-Paras, 2017	Posttraumatic Stress Disorder and Mobile Health: App Investigation and Scoping Literature Review	Not a systematic literature review or meta-analysis
Rootes-Murdy, 2018	Mobile technology for medication adherence in people with mood disorders: A systematic review	Lack of separate analysis
Sardi, 2017	A systematic review of gamification in e-Health	Lack of separate analysis
Sawesi, 2016	The Impact of Information Technology on Patient Engagement and Health Behavior Change: A Systematic Review of the Literature	Lack of separate analysis
Schlegl, 2015	The potential of technology-based psychological interventions for anorexia and bulimia nervosa: A systematic review and recommendations for future research	Lack of mental health app studies
Sin, 2018	eHealth interventions for family carers of people with long term illness: A promising approach?	Lack of separate analysis
Song, 2019	Mobile Health Interventions for Self-Control of Unhealthy Alcohol Use: Systematic Review	Lack of separate analysis
Stasiak, 2016	Computer-Based and Online Therapy for Depression and Anxiety in Children and Adolescents	Lack of mental health app studies
Struthers, 2015	The Acceptability of E-mental Health Services for Children, Adolescents, and Young Adults: A Systematic Search and Review	Lack of mental health app studies
Stuckey, 2017	The role of smartphones in encouraging physical activity in adults	Lack of relevant outcomes
Tamrat, 2012	Special delivery: An analysis of mHealth in maternal and newborn health programs and their outcomes around the world	Lack of separate analysis
van den Heuvel, 2018	eHealth as the Next-Generation Perinatal Care: An Overview of the Literature	Lack of separate analysis
Versluis, 2016	Changing Mental Health and Positive Psychological Well-Being Using Ecological Momentary Interventions: A Systematic Review and Meta-analysis	Lack of separate analysis
Wahle, 2017	Toward the Design of Evidence-Based Mental Health Information Systems for People with Depression: A Systematic Literature Review and Meta-Analysis	Lack of separate analysis
Werner-Seidler, 2018	Digitally-delivered cognitive-behavioural therapy for youth insomnia: A systematic review	Lack of mental health app studies
Whiteside, 2016	Mobile device-based applications for childhood anxiety disorders	Not a systematic literature review or meta-analysis
Williams, 2019	Internet-based interventions to support recovery and self-management: A scoping	Not a systematic literature review or meta-analysis

	review of their use by mental health service users and providers together	
Witt, 2017	Effectiveness of online and mobile telephone applications ('apps') for the self-management of suicidal ideation and self-harm: a systematic review and meta-analysis	Lack of separate analysis
Wozney, 2016	A systematic review of cognitive behavioral therapy and behavioral activation apps for depression	Lack of relevant outcomes
Wright, 2019	Computer-Assisted Cognitive-Behavior Therapy for Depression: A Systematic Review and Meta-Analysis	Lack of mental health app studies
Yang, 2019	The Comparative Effectiveness of Mobile Phone Interventions in Improving Health Outcomes: Meta-Analytic Review	Lack of separate analysis
Yang, 2015	Understanding computer-mediated health communication: Meta-analytical reviews of social-media-based interventions, online support group, and interactive health	Lack of mental health app studies
Young, 2018	Efficacy of online lifestyle interventions targeting lifestyle behaviour change in depressed populations: A systematic review	Lack of mental health app studies
Zhou, 2020	The effectiveness of mHealth interventions on postpartum depression: A systematic review and meta-analysis	Lack of mental health app studies
Pórarinsdóttir, 2017	Smartphone-Based Self-Assessment of Stress in Healthy Adult Individuals: A Systematic Review	Lack of relevant outcomes

Appendix B – Descriptive Summary of Included Reviews

First author, year	Type	Design (n)	Sample characteristics	Number of Articles (Total and App Outcomes)	Main findings	Quality
Batra, 2017	Systematic review	RCT (3) Randomised open-label (1) Randomised mixed method (1) Nonrandomised single arm (11) Nonrandomised parallel-arm (2)	Adults with serious mental illness: Schizophrenia/ Schizoaffective disorder Bipolar disorder Suicidality	Total: 18 Outcome studies: 10	<p>Clinical outcomes: Potential for apps to monitor and improve symptoms in serious mental illness in the short-term.</p> <p>Processes: No results</p> <p>Future research: Need for studies of long-term use, naturalistic use of apps, and larger samples.</p>	Critically Low
Camacho, 2019	Systematic review	Protocol (7) Case series (2) Observational cohort (1) Longitudinal feasibility (1) Feasibility (7) RCT (2) Pre-post pilot (1)	Adults with prodromal and early course psychosis and schizophrenia	Total: 21 Outcome studies: 3	<p>Clinical outcomes: Potential for apps to improve monitoring and interventions for psychosis. No single app fulfils all roles of specialist care. Low risk of harm in implementing apps.</p> <p>Processes: No results; discuss the potential benefits of peer support.</p> <p>Future research: Need for an evaluation and implementation framework to assist care providers in selecting toolkits comprising of several apps.</p>	Critically Low
Donker, 2013	Systematic review	RCT (5) Pilot RCT (1) Pre-post pilot (2)	Adults from community, out-patient clinic, nursing, students Adolescents from general practice	Total: 8 Outcome studies: 8	<p>Clinical outcomes: Potential for apps to improve symptoms of depression, anxiety, stress and possibly substance use.</p> <p>Processes: Mediation by increased emotional self-awareness</p> <p>Future research: High risk of bias in studies; high quality RCTs, or component testing recommended. Need for investigation of mediation effects.</p>	Moderate
Dubad, 2018	Systematic review	RCT (3) Non-experimental (22)	Young people (aged 10-24): Depression ASD Substance/alcohol users	Total: 25 Outcome studies: 5	<p>Clinical outcomes: Increase in emotional self-awareness and self-reflection, and fewer emotional difficulties following app-use. No</p>	Moderate

			Eating disorders Other emotional problems Non-clinical samples		direct investigations of negative effects, thus conclusions cannot be drawn. Processes: App use may give rise to emotional self-awareness, which serves to enhance improvements in depression. Future research: High-quality research recommended, currently much reliance on subjective feedback.	
Firth, 2017a	Meta-analysis	RCT (18)	Adults: Major depression Mild depression Bipolar disorder Suicidality General population	Total: 18 Outcome studies: 18	Clinical outcomes: Moderate positive effects of apps on depression symptoms compared with inactive controls ($g = 0.558$), high heterogeneity ($I^2=65.6\%$). Small effect of app compared with active controls ($g = 0.216$), moderate heterogeneity ($I^2=47.2\%$). Processes: None explored. Smaller effects of interventions when compared with active versus inactive control, suggesting possible expectancy effects. Future research: Further investigation of underlying mechanisms, e.g. engagement, feedback loops, expectancy effects, and individual app-user characteristics.	Moderate
Firth, 2017b	Meta-analysis	RCT (9)	Adults: Anxiety Healthy controls	Total: 9 Outcome studies: 9	Clinical outcomes: Apps significantly reduced total anxiety symptoms compared with inactive wait-list condition ($g = 0.452$) with moderate heterogeneity ($I^2 = 32\%$). Small effects of apps on anxiety compared with active controls ($g = 0.189$) with no heterogeneity. Processes: None explored. Smaller effects of interventions when compared with active versus inactive control,	Moderate

					suggesting possible expectancy effects.	
					Future research: Research needed to investigate processes of change, and/or expectancy/placebo effects	
Gould, 2019	Systematic review	RCT (6) Non-randomised pre-post (1) Preliminary study (2) Case series (2) Randomised case series (1) Uncontrolled pilot (1) Rapid ethnographic assessment (1) Cost-analysis (1) Clinician survey (4)	Adults at risk of developing disorder or seeking treatment for PTSD: Students Veterans Active service members Community sample	Total: 22 Outcome studies: 7	Clinical outcomes: Fewer studies reporting on outcomes compared with acceptability/feasibility studies. Overall a lack of evidence of efficacy for most apps. Processes: No results Future research: Rigorous research of efficacy and effectiveness required, with less variability in study design.	Critically Low
Goreis, 2020	Systematic review and meta-analysis	RCT (2) Pre-test post-test (4)	Adults with subthreshold or diagnosable PTSD	Total: 6 Outcome studies: 6	Clinical outcomes: Small to moderate effects of apps in reducing PTSD symptoms ($g = 0.55$). No difference between app intervention and waitlist control for PTSD symptoms. Processes: No results Future research: Requirement for investigations of guided and unguided support via apps. Investigations with mediation analyses required to better understand processes underlying efficacy.	Moderate
Grist, 2017	Systematic review	RCT (3) Pre-post (1) Case study (1) App-analysis (2) App-design (5) Feasibility (12)	Young people (9-30 years): Community samples Anxiety disorders Body image concerns Suicidality	Total: 24 Outcome studies: 5	Clinical outcomes: No significant effects of apps on mental health outcomes amongst young people. Fewer studies assessing outcomes compared with feasibility/acceptability studies. Processes: No results Future research: High quality research with robust designs and adequate power required to demonstrate efficacy, effectiveness, and safety of apps used in isolation. More research investigating efficacy	Low

					amongst younger samples.	
Ilagan, 2020	Systematic review and meta-analysis	RCT (5) Pre-test post-test (7)	Adults with symptoms commonly occurring in borderline personality disorder (BPD; anger, suicidality, self-harm)	Total: 12 Outcome studies: 12	<p>Clinical outcomes: Mixed results, with some demonstrations of improvements in distress and urges to use substances. Pooled outcomes show no evidence of benefits. Some participants reported to attempt suicide. Insufficient evidence to recommend apps.</p> <p>Processes: No results</p> <p>Future research: Studies with standard, reliable measures of BPD, more follow-up studies, exploration of processes.</p>	High
Kerst, 2019	Systematic review	RCT (3) Pilot RCT (2) Single-arm pilot (2) Prospective control group (1)	Adults: Mild, moderate, and clinical depression	Total: 12 Outcome studies: 8	<p>Clinical outcomes: Promising results due to reduction of depression symptoms; evidence base is still limited.</p> <p>Processes: Difficult to isolate effects when apps used alongside traditional therapy.</p> <p>Future research: Need to research which components of mHealth interventions are effective. Need for more clinical samples.</p>	Moderate
Linardon, 2019	Meta-analysis	RCT (66)	<p>Adults: Depression Anxiety Stress PTSD</p> <p>Adolescents: Depression</p> <p>Young adults: Stress Depression</p>	Total: 39 Outcome studies: 39 (several studies included within a single article)	<p>Clinical outcomes: Promising results for social anxiety ($g = 0.76$), panic ($g = 0.12$) and generalised anxiety ($g = 0.39$) when adjusting for RoB or publication bias. Smartphones also show benefits over control conditions for quality of life, and positive affect across symptomatic and non-symptomatic samples. No differences for panic, PTSD, or negative affect.</p> <p>Processes: No results, but some consideration of theoretical model of apps.</p> <p>Future research: Research required to explore potential negative effects of apps, along</p>	Moderate

					with long-term efficacy. Need for RCTs to compare apps underpinned by different theoretical orientations.	
Linardon, 2020	Systematic review and meta-analysis	RCT (27)	Adults using Acceptance and Commitment Therapy (ACT) apps: Stress Physical ill health Smokers Mood disorders Self-criticism General population	Total: 27 Outcome studies: 27	Clinical outcomes: High risk of bias, limited ability to demonstrate effectiveness, particularly compared with face-to-face or computerised treatments. Changes in mindfulness and acceptance associated with reduction in distress. Processes: Possibility that mindfulness and acceptance may be involved in change; no conclusions can be drawn. Future research: Need for investigations to quantify digital placebo effects, and dose-response relationship. Mediation analyses also required.	Moderate
Lui, 2017	Systematic review	RCT (5) Pilot RCT (7) Preliminary study (3) Pilot feasibility (2) Pre-post (1) Yoked control (1) Single-arm trial (1) Quasi-experimental (1)	Adults: Anxiety disorders Mood disorders PTSD Schizophrenia Substance use disorders	Total: 21 Outcome studies: 21	Clinical outcomes: Significant reductions in symptoms, insufficient evidence to support mental health apps (lack of replication, lack of between group differences). Processes: No research; discuss the potential for placebo effects. Future research: Need for comparison groups and replications for more robust evidence base. Requirement for iatrogenic effects to be investigated.	Critically Low
Melia, 2020	Systematic review	RCT (5) Pre-post trial (1)	Adults and adolescents with current risk of suicide or history of self-harm or suicidal behaviours	Total: 4 Outcome studies: 4 (one such article outlines 3 studies)	Clinical outcomes: Promising results demonstrated of apps reducing self-harm and suicidal ideation alongside face-to-face therapy. Research is not sufficient to prescribe apps as standalone interventions. Processes: No results Future research: Requirement to address methodological issues in future studies. Need for	Moderate

					investigation of ecological momentary assessment delivery via mobile app.	
Menon, 2017	Systematic review	RCT (14) Pilot RCT (1) Pre-post (1) Preliminary study (2) Development protocol (2) Protocol RCT (2) Design (2)	Adults: Depression Bipolar disorder Schizophrenia Psychotic disorders Substance use disorders Non-clinical samples Children/Adolescents: Anxiety Community sample	Total: 24 Outcome studies: 18	Clinical outcomes: Promising results of apps improving clinical symptoms; however, limited number of trials. Processes: No results Future research: Research required on side effects, real-world outcomes, innovative RCTs, qualitative feedback from patients and providers, cost-effectiveness, ethical and confidentiality issues.	Critically Low
Punukollu, 2019	Systematic review	RCT (1; reported by 3 publications.) Cross-sectional (1)	Children and young people (10–29 years): Depression Stress Anxiety	Total: 6 Outcome studies: 4	Clinical outcomes: Not yet sufficient evidence for adoption of mHealth amongst young people, due to limited research. Processes: Mediation by emotional self-awareness. Future research: More attention to mHealth interventions amongst this age group. Investigation of ethical issues regarding clinical risk and confidentiality. Existing apps require evaluation rather than development of new apps. Need for investigation of client preferences.	Moderate
Rathbone, 2017	Systematic review	RCT (8)	Adults: PTSD (untreated) Major depressive disorder Mild to moderate depression Mild insomnia Chronic pain Stress Adolescent: School students (13-17 years)	Total: 8 Outcome studies: 8	Clinical outcomes: Apps utilising CBT demonstrate improvements. No evidence for longevity. Processes: No results Future research: Recommendation for long-term follow-up data, larger datasets, more professional involvement in app-development.	Moderate
Rathbone and Prescott, 2017	Systematic review	RCT (19) Within-group study (8)	Adults: Major depressive disorder Mild to moderate depression Anxiety Stress General population Other physical health	Total: 27 Outcome studies: 9	Clinical outcomes: Positive effects of apps on both physical and mental health. Processes: No results Future research: Recommendation for	Moderate

			Child and adolescent: School students (13-17 years) Anxiety		more stringent, high-quality RCTs and longitudinal studies to investigate relapse, sustainability, and effectiveness.	
Shin, 2017	Systematic review	RCT (12) Pre-post (3) Case study (1)	Adult: Veterans Obstructive sleep apnoea Community sample Breast cancer survivors Insomnia First-time mothers Pilots Mild traumatic brain injury Older adult: Insomnia Obstructive sleep apnoea Young adult: Smokers	Total: 16 Outcome studies: 7	Clinical outcomes: Studies predominantly support efficacy of apps, text message interventions, and mobiles as auxiliary equipment. Processes: No results Future research: Need for more RCTs and comparison with treatment-as-usual and wait-list control groups.	Moderate
Wang, 2018	Systematic review	RCT (6) Feasibility (2) Pre-post (1) Case cross-over (1) Focus group (2) Survey (1) Design (2) Semi-structured interview (1) Pilot (1)	Adults: Alcohol disorder Suicidality PTSD Anxiety Sleep disorders Children/Adolescents: PTSD	Total: 17 Outcome studies: 17	Clinical outcomes: Potential for effectiveness of apps on a range of mental health presentations. Only a small proportion of available apps clinically validated. Processes: No results Future research: Further robust studies required to develop evidence-based programs, and to clinically validate apps.	Critically Low
Weisel, 2019	Systematic review and meta-analysis	RCT (19)	Adults: Depression, self-injury, suicidal behaviour Anxiety PTSD Sleep problems Substance use	Total: 17 Outcome studies: 17 (one of which article outlines 3 studies)	Clinical outcomes: Lack of generalisable evidence supporting apps. Promising pooled effects for depression ($g = 0.33$) and smoking cessation ($g = 0.39$), but no pooled effects for anxiety, alcohol use, and self-injurious thoughts/behaviours. High heterogeneity and non-consistent with other mHealth effects. Processes: No results. Future research: Understanding of mechanisms required, in addition to long-term effects of apps. Investigation of specific features of apps required (context sensing,	Moderate

					constant access, availability, prompts).	
Wickersham, 2019	Systematic review	RCT (3) Pilot RCT (2)	Adults PTSD	Total: 5 Outcome studies: 5	<p>Clinical outcomes: Inconclusive evidence, due to high risk of bias across studies, and lack of long-term investigations.</p> <p>Processes: No results</p> <p>Future research: More research needed on long-term effects of app-use, using rigorous, large-scale samples, with feedback from app-users.</p>	Moderate
Zhao, 2017	Systematic review	RCT (55)	Adults and adolescents: Mild, moderate and severe depression	Total: 55 Outcome studies: 2	<p>Clinical outcomes: Some support for CBT apps on depression symptoms. Less evidence available for mHealth compared with other information technology or web-based interventions.</p> <p>Processes: No results</p> <p>Future research: Requirement for more RCTs and meta-analyses.</p>	Critically Low

Note: RoB = Risk of Bias

Appendix C – Overlap of Outcome Studies across Reviews

First author, Date	Reviews
Arean, 2016	Firth(b), Kerst, Linardon(b), Rathbone(b), Weisel
Babson, 2015	Gould, Shin
Ben-Zeev, 2014	Batra, Lui, Menon, Rathbone(b)
Birney, 2016	Firth(b), Linardon(b), Rathbone(a), Weisel
Bricker, 2014	Linardon(a), Lui
Burns, 2011	Donker, Lui
Bush, 2015	Gould, Wang
Bush, 2017	Gould, Ilagan, Melia
Cox, 2019	Linardon(a), Linardon(b)
Depp, 2015	Firth, Menon
Ebert, 2016a	Linardon(a), Linardon(b)
Ebert, 2016b	Linardon(a), Linardon(b)
Enock, 2014	Firth(a), Firth(b), Linardon(b), Lui, Menon, Weisel
Faurholt-Jepsen, 2015	Batra, Firth(b), Linardon(b)
Flett, 2019	Linardon(a), Linardon(b)
Franklin, 2016	Ilagan, Melia, Weisel
Gajecki, 2014	Wang, Weisel
Gustafson, 2014	Lui, Menon
Harrer, 2018	Linardon(a), Linardon(b)
Heber, 2016	Linardon(a), Linardon(b)
Horsch, 2017	Firth(b), Linardon(b), Rathbone(a), Weisel
Howells, 2016	Firth(a), Linardon(b)
Ivanova, 2016	Firth(a), Firth(b), Linardon(b)
Kahn, 2016	Firth(b), Linardon(a), Linardon(b), Wickersham
Kauer, 2012	Donker, Dubad, Grist, Linardon(b), Menon, Pudukollu, Rathbone(b)
Kenny, 2015	Dubad, Grist
Koffel, 2016	Gould, Shin
Krafft, 2019	Linardon(a), Linardon(b)
Kristjánsdóttir, 2013	Linardon(a), Rathbone(a)
Kuhn, 2014	Gould, Wang
Kuhn, 2017	Firth(b), Goreis, Gould, Linardon(b), Rathbone(a), Weisel, Wickersham
Lappalainen, 2013	Kerst, Linardon(a)
Ly, 2014a	Batra, Kerst, Linardon(a), Menon, Rathbone(a)
Ly, 2014b	Rathbone(a), Rathbone(b)
Ly, 2015	Firth(b), Rathbone(a)
Matthews, 2008	Dubad, Grist
Matthews, 2011	Dubad Grist
Miner, 2016	Goreis, Gould, Lui, Weisel, Wickersham
Mistretta, 2018	Linardon(a), Linardon(b)
Moëll, 2015	Firth(a), Firth(b)
Nobis, 2015	Linardon(a), Linardon(b)
Oh, 2017	Firth(b), Linardon(b)
Palmier-Claus, 2012	Batra, Camacho

Pham, 2016	Firth(a), Linardon(b), Rathbone(b), Wang, Weisel
Possemato, 2016	Goreis, Gould, Lui, Wang, Wickersham
Proudfoot, 2013	Firth(a), Firth(b), Linardon(b), Menon, Rathbone(b), Zhao
Reid, 2011	Donker, Dubad, Firth (a), Grist, Pudukollu
Reid, 2013	Dubad, Grist, Pudukollu
Rizvi, 2011	Donker, Ilagan, Lui
Roepke, 2015	Firth(a), Firth(b), Linardon(b), Lui, Weisel
Roy, 2017	Goreis, Wickersham
Tighe, 2017	Firth(b), Ilagan, Linardon(b), Melia, Weisel
van Drongelen, 2014	Shin, Wang
Versluis, 2018	Linardon(a), Linardon(b)
Villani, 2013	Donker, Menon
Watts, 2013	Batra, Donker , Firth (b), Kerst, Lui, Menon, Rathbone(b), Zhao
Whittaker, 2012	Rathbone(a), Rathbone(b)
Witkiewitz, 2014	Lui, Weisel
