Digital Interventions for People With Co-Occurring Depression and Problematic Alcohol Use: A Systematic Review and Meta-Analysis

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Abstract

Aims: This systematic review and meta-analysis assessed the effectiveness of digital interventions addressing depressive symptoms and alcohol use simultaneously among people with co-occurring depression and problematic alcohol use.

Methods: Seven databases were searched for trials evaluating digital interventions aimed at depression and alcohol use. Random-effects meta-analyses were conducted to pool effects on depressive symptoms and alcohol use up to 3-month and 6-month follow-up. Overall quality for every outcome was assessed with GRADE (Grading of Recommendations Assessment, Development, and Evaluation).

Results: The pooled effect of digital interventions compared to their comparators was in favour of digital interventions. Small but significant effects on depressive symptoms at 3-month follow-up were found ($g = 0.34, 95\%$ confidence interval (CI): 0.06–0.62, $P = 0.02, k = 6$) and non-significant effects at 6-month follow-up ($g = 0.29, 95\%$ CI: −0.16 to 0.73, $P = 0.15, k = 5$). For alcohol use, the pooled effect of digital interventions was small and non-significant at 3-month follow-up ($g = 0.14, 95\%$ CI: −0.02 to 0.30, $P = 0.07, k = 6$) and significant at 6-month follow-up ($g = 0.14, 95\%$ CI: 0.07–0.20, $P = 0.005, k = 5$). Sensitivity analysis indicated the latter finding to be sensitive to statistical estimator choice. Quality of evidence was moderate, except for depressive symptoms at 6-month follow-up for which it was low.
Conclusion: Based on the literature, digital interventions are effective in reducing depressive symptoms at 3-month follow-up and alcohol use at 6-month follow-up among people with comorbid depression and problematic alcohol use. More high-quality trials are needed to confirm the current findings.

INTRODUCTION

Depressive disorders and alcohol use disorders (AUD) are common mental disorders that often co-occur (Grant et al., 2015; Degenhardt et al., 2018). The co-occurrence of these two conditions has been extensively studied in various epidemiological studies (Grant et al., 2004; Boden and Fergusson, 2011; Lai et al., 2015). A meta-analysis on epidemiological surveys conducted between 1990 and 2014 shows that people with AUD are at 2.4 times greater risk of having major depression (Lai et al., 2015). Also, in alcohol users in general, higher levels of alcohol use are associated with higher levels of depressive symptoms (Hovrath et al., 2019). Furthermore, individuals with depressive disorders have a threefold increased risk of lifetime AUD (Boschloo et al., 2011). Comorbid depression and problematic alcohol use are associated with increased risk of greater AUD severity, suicide attempts, higher disease burden and lower life satisfaction and general functioning compared to both conditions alone (Gadermann et al., 2012; Briere et al., 2014). In this review, we use the term ‘problematic alcohol use’ to refer to AUD as well as other non-clinical levels of hazardous drinking.

Psychosocial treatment of co-occurring depression and problematic alcohol use can be based on a single or dual disorder approach (Hobden et al., 2018). In the latter, both comorbid conditions are treated simultaneously. This combined treatment approach has never been common practice (Riper et al., 2014a). Often the comorbid disorder was either not recognized or not treated, assuming that when the primary disorder (e.g. problematic alcohol use) was treated, the other disorder (e.g. depression) would improve as well or vice versa (Schuckit, 2006; Pettinati et al., 2013). Research does indeed show that depressive symptoms decrease after treatment for problematic alcohol use. However, not all individuals with comorbid problematic alcohol use and depression experience complete remission of depressive symptoms and might therefore be more prone to a relapse (Schuckit, 2006; Hobden et al., 2018).

Nowadays, more combined psychological treatments are available for co-occurring depression and problematic alcohol use. These combined treatments are often based on cognitive–behavioural therapy (CBT) and motivational interviewing (MI). CBT is a common and effective treatment for depressive disorders and is aimed at changing a patient’s behaviour and functioning through cognitive–behavioural restructuring of maladaptive beliefs (Beck et al., 1979; Cuijpers et al., 2020). MI is used to facilitate behaviour change (e.g. drinking behaviour) through enhancing motivation and commitment to change and by resolving ambivalence about change (Miller and Rollnick, 2012; Frost et al., 2018). Both CBT and MI-based treatments have been proven to be effective treatments for reducing independent depression and problematic alcohol use (Vasilaki et al., 2006; Kohler and Hofmann, 2015; Cuijpers et al., 2020).

For co-occurring depression and problematic alcohol use, CBT/MI-based treatments also seem promising. A meta-analysis by Riper et al. (2014a) shows that combined CBT/MI-based treatment can be effective in reducing both depressive symptoms (g = 0.27) and alcohol use (g = 0.17) compared to treatment as usual, among people with comorbid depression and problematic alcohol use. Notably, subgroup analyses indicated that digital CBT/MI treatments had a significantly higher effect on depression outcomes compared to face-to-face treatments (g = 0.73 vs. g = 0.23) (Riper et al., 2014a).

A recent systematic review also showed positive effects of digital interventions on mental health symptom severity for people with co-occurring depression and substance use disorders. Improvement in both comorbid conditions was only observed in half of the studies that were under review. However, no meta-analysis was conducted by the authors (Holmes et al., 2018).

In the last decade, numerous digital interventions have been developed for either depression or problematic alcohol use. Digital interventions often include psychoeducation, CBT/MI-based support or therapy and are delivered through the Internet, computer or a mobile device. They can be self-guided or may include therapy-related feedback from a therapist or (technical) process support (Richards and Richardson, 2012; Callan et al., 2017; Cuijpers et al., 2017). Many reviews have already shown the effectiveness of digital interventions in reducing independent depressive symptoms and alcohol use in various settings, such as community (Deadly et al., 2017; Kaner et al., 2017), among youth (Hollis et al., 2017; Christ et al., 2020), students and young adults (Davies et al., 2014; Sundstrom et al., 2017; Harrer et al., 2019a), adults (Riper et al., 2014b; Sundstrom et al., 2017; Riper et al., 2018) and also for guided and self-guided CBT-based interventions (Karyotaki et al., 2017, 2018), although effect sizes are often in the small range.

Currently, a few combined digital interventions are available that address depressive symptoms and problematic alcohol use simultaneously. No meta-analysis has yet been conducted on the effectiveness of digital interventions for people with co-occurring depression and problematic alcohol use specifically. The present study reports the results of a systematic review that evaluated the outcomes of randomized controlled trials (RCTs) on digital interventions addressing depressive symptoms and problematic alcohol use simultaneously among adults with co-occurring depression and problematic alcohol use.

METHODS

This study was reported in accordance with the PRISMA guidelines for reporting systematic reviews and meta-analyses (Moher et al., 2009). The review protocol was pre-registered in the International Prospective Register of Systematic Reviews (PROSPERO: CRD42018108299).

Search strategy

We conducted an extensive literature search from database inception to June 8th 2020. Seven electronic databases were searched: PubMed, EMBASE, PsycINFO, CINAHL, Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science and Scopus. A research librarian assisted with developing the search string (see Supplementary Material S1). We included studies that were published in the last 15 years but did not restrict our search. We were therefore
able to identify if any eligible studies were published before this publication date, this appeared not to be the case. There were no language limitations, but studies needed to have an English abstract to be identified in the search.

The search string included MeSH (Medical Subject Headings) terms, text words and synonyms related to problematic alcohol use, depression and digital interventions and were combined with Boolean operators AND/OR. We also checked reference lists of relevant reviews and searched the WHO International Clinical Trials Registry Platform for eligible studies.

Eligibility criteria
Studies were included if they were (a) based on a RCT study design and (b) reported effects of a digital intervention that targeted both depressive symptoms and alcohol use simultaneously (c) compared to any type of control group (e.g. waitlist, active treatment, assessment only, attention control) and (d) reported both depression and alcohol use outcomes and were (e) conducted among adults with depression or elevated depressive symptoms and any form of problematic alcohol use. Digital interventions were defined as interventions including digital environments to access information, modules, feedback or assignments.

Study selection
Study selection was conducted by M.J.E.S. and C.C. and was supervised by a third senior researcher (M.B.). After every phase, any disagreements were discussed until consensus was reached. If needed, the supervising researcher was consulted. All studies identified by the search were uploaded into Rayyan Citation after duplicates were removed (Ouzzani et al., 2016). M.J.E.S. and C.C. independently assessed the full texts for final inclusion.

Data extraction
Data extraction was conducted by M.J.E.S. and checked for inconsistencies by C.C. The following data were extracted: (a) study characteristics: authors, publication year, country; (b) participant characteristics: population, recruitment setting; sample size, mean age, gender; (c) intervention characteristics: intervention type, delivery mode, duration, guidance, adherence; (d) outcome measures: type of depression or alcohol-related outcomes, follow-up (e) and type of comparator. For the meta-analysis, necessary quantitative data (e.g. depression or alcohol-related outcomes, follow-up (e) and type of comparator. For the meta-analysis, necessary quantitative data (e.g. mean (M) and standard deviation (SD)) were extracted.

When a study had multiple comparators, we included the comparator to which the authors themselves referred to as the control condition. As indicated in our review protocol, we extracted alcohol consumption outcomes (number of standard drinks) and outcomes measuring depressive symptoms. When multiple follow-up measurements were reported, those closest to 3 and 6 months were included in the meta-analyses.

Quality assessment
All quality assessments were independently conducted by M.J.E.S. and C.C. and supervised by M.B. Any disagreements between M.J.E.S. and C.C. were discussed until consensus was reached.

Risk of bias
We used the revised Cochrane Risk of Bias tool (RoB 2.0) to assess risk of bias for every included study (Sterne et al., 2019). Five domains were assessed for risk of bias: (a) randomization process, (b) deviations from intended interventions, (c) missing outcome data, (d) measurement of the outcome and (e) bias in selection of the reported result. Using the RoB 2.0 guidelines, we first came to domain-level judgements of low, some concerns or high risk of bias. Second, we used these domain-level judgements to reach an overall risk of bias judgement. If all domains were rated with low risk of bias, an overall low risk of bias was given. If at least one domain scored a judgement of some concerns and no domain was high risk of bias, then an overall judgement of some concerns was given. An overall high risk of bias was given when at least one domain was assessed as such (Sterne et al., 2019).

Overall quality of evidence
Grading of Recommendations Assessment, Development and Evaluation (GRADE) was used to assess the overall quality of evidence for every pooled outcome (Schünemann et al., 2013). We assessed the five domains: (a) risk of bias, (b) inconsistency of results (i.e. heterogeneity), (c) indirectness of evidence, (d) imprecision of results and (e) suspected publication bias. All outcomes started as high-quality evidence, because all included studies were RCTs. We downgraded the level of evidence when limitations in any of the domains occurred. The overall quality was assessed as either high, moderate, low or very low (Schünemann et al., 2013).

Meta-analysis
Main analyses All meta-analytic procedures were conducted using the meta, metafor and dmetar packages in R version 3.6.0 (Schwarzer, 2007; Viechtbauer, 2010; R Core Team, 2018; Harrer et al., 2019b). The esc package was used to calculate between-group effect sizes with a small sample bias correction (Hedges’ g) for every study; M and SD were used if present and otherwise the Cohen’s d and P value were used using dmetar package (Lüdecke, 2018; Harrer et al., 2019b). We used a random-effects model with the Harrung-Knapp-Sidik-Jonkman (HKSJ) estimator as the main analysis because of the small number of studies and anticipated heterogeneity (IntHout et al., 2014). Simulation studies have shown that the HKSJ estimator often performs better than the frequently used DerSimonian-Laird (DL) estimator, especially when there is heterogeneity and the number of pooled studies is small (IntHout et al., 2014). The random-effects model was used to pool the individual studies’ effect sizes to a standardized mean difference (SMD) Hedges’ g for both depression and alcohol use outcomes (Hedges and Olkin, 2014). A positive Hedges’ g indicates a decrease in alcohol use or depressive symptoms. We calculated the number needed to treat (NNT) for the pooled SMDs, using the formulae by Kraemer and Kupfer (2006). The NNT indicates the number of patients needed to be treated to generate one additional positive outcome (Kraemer and Kupfer, 2006). Heterogeneity was examined by calculating the I² statistic and corresponding confidence intervals. T² and Q-statistic were calculated as additional heterogeneity measures (Borenstein et al., 2017). An I² statistic of 25% indicates low heterogeneity and 50% and 75% indicates moderate and substantial heterogeneity, respectively (Higgins et al., 2003). Prediction intervals (PI) were calculated and provide a range between which effects of future studies are expected to fall. A PI range that includes zero indicates that in some settings,
future studies on digital interventions may find no or even negative
effects on depression or alcohol outcomes (IntHout et al., 2016).

**Additional analyses** We conducted sensitivity analyses using the DL estimator to examine to what extent findings from the main analyses were sensitive to our choice to use the HKS estimator (Wiksten et al., 2016). Influence analysis was conducted to evaluate the influence of a single study on the pooled effect size (i.e. robustness of the pooled effect size). Influential cases and outliers were examined by using the leave-one-out method, by removing the highest and lowest effect size and outlier identification and removal (Viechtbauer and Cheung, 2010).

**RESULTS**

**Selection and inclusion of studies**
The database search resulted in a total of 12173 articles. After duplicates removal, 5664 unique articles were screened for eligibility based on title and abstract, of which 5628 articles were excluded (98% reviewers agreement). We retrieved full texts of 36 articles, and...
### Table 1. Study characteristics of included studies

<table>
<thead>
<tr>
<th>Author, country, year</th>
<th>Population, alcohol/ depression criteria</th>
<th>Recruitment setting</th>
<th>Sample characteristics</th>
<th>Intervention description</th>
<th>Delivery mode</th>
<th>Duration intervention</th>
<th>Guided</th>
<th>Adherence intervention</th>
<th>Comparator</th>
<th>Depression/alcohol outcomes a</th>
<th>Follow-up</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agyapong et al. (2012, 2016)</td>
<td>Alcohol dependence (syndrome)/alcohol use; AOD, alcohol and other drugs</td>
<td>Inpatient (diagnostic) treatment programme</td>
<td>N = 54, Female = 46% Mean age = 49</td>
<td>Twice-daily supportive text messages after discharge</td>
<td>Mobile phone</td>
<td>3 months</td>
<td>No</td>
<td>No</td>
<td>Active: TAU (usual aftercare)</td>
<td>Depression symptoms (BDI-II)</td>
<td>3 months</td>
<td>ITT</td>
</tr>
<tr>
<td>Deady et al. (2016)</td>
<td>Alcohol and other drugs</td>
<td>Online/online media advertisement</td>
<td>N = 114, Female = 66.7% Mean age = 22</td>
<td>Four weekly online CBT/MI modules (1 hour) with homework assignments</td>
<td>Website</td>
<td>10 weeks</td>
<td>No</td>
<td>Average of 1.5 modules completed b</td>
<td>Passive</td>
<td>Attention control condition</td>
<td>Depression severity (PHQ-9)</td>
<td>Posttreatment</td>
</tr>
<tr>
<td>Geissner et al. (2015)</td>
<td>Alcohol dependence (syndrome)/alcohol use</td>
<td>College students</td>
<td>N = 170, Female = 62% Mean age = 26</td>
<td>One session of personalized feedback + psychosocial interventions (responses on alcohol use and consequences, protective behavioral strategies, normative perceptions and depression symptoms and coping strategies)</td>
<td>Computer</td>
<td>5 weeks</td>
<td>No</td>
<td>92% participated in intervention</td>
<td>Active: Attention control condition</td>
<td>Depression symptoms (BDI-II)</td>
<td>1 month</td>
<td>ITT</td>
</tr>
<tr>
<td>Kay-Lambkin et al. (2009)</td>
<td>Alcohol (MDD), multiple</td>
<td>Clinical</td>
<td>N = 471, Female = 44% Mean age = 42</td>
<td>Brief intervention (10 f2f sessions with therapist)</td>
<td>Computer</td>
<td>3 months</td>
<td>Yes</td>
<td>47% c completed all sessions</td>
<td>Active: TAU (usual aftercare)</td>
<td>Depression symptoms (BDI-II)</td>
<td>3 months</td>
<td>CO</td>
</tr>
<tr>
<td>Kay-Lambkin et al. (2011)</td>
<td>Alcohol dependence (syndrome)/alcohol use</td>
<td>Clinical</td>
<td>N = 471, Female = 44% Mean age = 42</td>
<td>9 weeks of computer CBT/MI aimed at integrated depressive and alcohol-related strategies</td>
<td>Computer</td>
<td>9 weeks</td>
<td>No</td>
<td>30% c completed all sessions</td>
<td>Active: Attention control condition</td>
<td>Depression symptoms (BDI-II)</td>
<td>3 months</td>
<td>ITT</td>
</tr>
<tr>
<td>O’Reilly et al. (2019)</td>
<td>Alcohol dependence (syndrome)/alcohol use</td>
<td>Inpatient (diagnostic) treatment programme</td>
<td>N = 80, Female = 48% Mean age = 42</td>
<td>Twice-daily supportive text messages after discharge aimed at alcohol abstinence and depression/mood in addition to usual aftercare</td>
<td>Mobile phone</td>
<td>6 months</td>
<td>No</td>
<td>No</td>
<td>Active: TAU (usual aftercare)</td>
<td>Depression symptoms (BDI-II)</td>
<td>3 months</td>
<td>CO</td>
</tr>
</tbody>
</table>

AD, alcohol dependence; AOD/AA, alcohol dependence (syndrome)/alcohol abuse; AOD, alcohol and other drugs; AUS, Australia; BDI, Beck Depression Inventory; Clinical sample, confirmed diagnosis; CO, completers only; f2f, face-to-face; IRE, Ireland; ITT, intention to treat; MDD, major depressive disorder; MDE, major depressive episode; N, total number of participants in meta-analysis, multiple N indicates different sample sizes per timing and outcome measurement; Ns, not reported; SCID, Structured Clinical Interview for DSM-IV Axis I Disorders; Selected sample, scoring above cut-off thresholds for depressive symptoms/problematic alcohol use; PHQ-9, Patient Health Questionnaire-9; w/m, women/men.

a The follow-up and outcome measures in italic were included in the meta-analysis.

b % of all participants allocated to intervention.

c Total sample (including multiple comparators not all included in meta-analysis).

Mixed sample and sample size estimated, number of participants in depression analysis.

Mixed sample and sample size estimated, number of participants in alcohol analysis.

Total sample at baseline.
8 articles met all inclusion criteria. When trial results were reported in multiple articles (e.g. when outcomes after 3- and 6-month follow-up were published in two separate articles), we combined the articles into one independent study. Six independent studies were included in the meta-analysis, see Fig. 1.

Study characteristics

Study population All studies were published between 2009 and 2019 and conducted in Australia (k = 3), Ireland (k = 2) and the United States (k = 1). Three studies were conducted on clinical depression samples and three studies on selected study samples based on elevated depressive symptoms scores, indicating moderate depression symptomology and problematic alcohol use above certain thresholds. Participants’ mean age ranged from 20 to 49 years (see Table 1).

Outcomes measurements Studies reported outcomes at posttreatment (k = 1), 1-month (k = 1), 3-month (k = 5), 6-month (k = 5) and 12-month follow-up (k = 3). We pooled effects closest to 3-month (i.e. 1–3 months) and 6-month follow-up. Five studies reported depressive symptoms as scores on the Beck Depression Inventory-II questionnaire and one used the Patient Health Questionnaire-9. Alcohol use outcomes included units per drinking day (k = 2), drinks per week (k = 2) and mean number of alcohol use occasions per day (k = 2).

Comparators Four studies included active control groups, either treatment as usual (TAU) or therapist face-to-face delivered sessions. Two others included passive control groups, namely attention control condition and assessment only.

Digital interventions and adherence Two digital interventions were delivered via mobile phone and composed of receiving twice-daily supportive text messages aimed at abstinence and improvement in depressive symptoms in addition to usual care, for people discharged from a dual disorder inpatient treatment programme (Agyapong et al., 2012, 2013a; O’Reilly et al., 2019). Four interventions were computer delivered, three of which included online CBT/MI modules aimed at reducing alcohol use and depressive symptoms (Kay-Lambkin et al., 2009, 2011, 2017; Deady et al., 2016). Two of these CBT/MI-based interventions included 10- to 15-minute therapist face-to-face guidance as an add-on, four digital interventions were self-guided. Lastly, one computer-delivered intervention included tailored feedback regarding alcohol use and depressive symptoms, incorporating protective behavioural strategies, coping strategies, psychoeducation and comparisons of participants’ own drinking with perceived drinking norms (Geisner et al., 2015).

Digital intervention adherence rates varied and were differently operationalized. One study reported that 92% of the participants participated in the intervention (Geisner et al., 2015), two studies reported that 47% and 30% of the participants completed all sessions (Kay-Lambkin et al., 2009, 2011, 2017) and another study reports an average of 1.5 completed modules out of a total of 4 (Deady et al., 2016). Two studies did not report adherence rates (Agyapong et al., 2012, 2013b; O’Reilly et al., 2019).

Quality assessment

Risk of bias assessment All six studies were assessed with an overall high risk of bias, because of high-risk domain judgements on one (k = 3), two (k = 2) or three domains (k = 1) (see Fig. 2). All studies were rated high risk of bias in the measurement of the outcome, mostly because of use of self-report measurements and the inability of blinding participants. In self-report measures, the participant himself or herself is the assessor; consequently, the participants’ knowledge about the received intervention (i.e. control or experimental group) could have influenced the outcome measurements and might cause bias (Sterne et al., 2019). Three studies had a high risk of bias rating because of ≥5% missing data and handling of it (e.g. no sensitivity analysis or no multiple imputation). One study was rated high risk of bias for the fifth domain because of unexplained deviations from the protocol. The inability of blinding participants and use of self-report measures is common in psychological studies. If the fourth domain is omitted, three studies would still have an overall high-risk judgement and three others a some concerns judgement.

GRADE assessment The overall quality of the evidence was moderate for alcohol use at 3- and 6-month follow-up and for depressive symptoms at 3-month follow-up. We downgraded the quality of evidence for these outcomes because of the high risk of bias ratings. Overall quality for depressive symptoms at 6-month follow-up was assessed as low, because of limitations in both risk of bias and inconsistency domains (due to moderate heterogeneity). We were unable to empirically examine publication bias because of the small number of studies in this review (Higgins et al., 2019) (see Table 2).

Meta-analyses

The meta-analyses on depressive symptoms at 3- and 6-month follow-up were conducted on a total sample of 647 and 461 participants, respectively. For alcohol use at 3- and 6-month follow-up, the sample included 449 and 375 participants, respectively. Sample size variation is caused by one study that only included 1-month follow-up (Geisner et al., 2015). Additionally, two studies were conducted on mixed samples (Kay-Lambkin et al., 2009, 2011, 2017).

Depressive symptoms In the main analysis, the overall pooled effect size of digital interventions on depressive symptoms at 3-month follow-up was small but significant, with g = 0.34 (P = 0.02, 95% confidence interval (CI): 0.06–0.62, k = 6), which corresponds with an NNT of 5.26 (see Table 2 and Fig. 3). Heterogeneity was low to moderate (I² 27%, 95% CI: 0–70%). The PI ranged from g = 0.30 to 0.98, indicating that in future similar studies, the effect could as well be either positive or negative on depressive symptoms. The additional analyses showed similar results: sensitivity analysis resulted in g = 0.32 (P = 0.0014), no outliers were detected and influence analyses showed significant but somewhat fluctuating small effects (g = 0.25, P = 0.02 and g = 0.41, P = 0.02), which means findings are sufficiently robust and do not heavily depend on an individual study.

In the main analysis, the pooled effect size for depressive symptoms at 6-month follow-up was small and non-significant with g = 0.29 (P = 0.15, 95% CI: −0.16 to 0.73, k = 5). Heterogeneity was moderate (I² 48%, 95% CI: 0%–81%), and PI ranged from −0.73 to 1.32. Additional analyses showed similar non-significant effects, with g = 0.27 (P = 0.08) in sensitivity analyses and effect sizes ranging from g = 0.11 to 0.40 (P = 0.22 and 0.11, respectively) in influence analysis.

Alcohol use In the main analysis, the overall pooled effect size for digital interventions compared to control groups on alcohol
use at 3-month follow-up was small and non-significant, with \( g = 0.14 \) (\( P = 0.07, 95\% \text{ CI: } -0.02 \text{ to } 0.30, k = 6 \)). Heterogeneity was low (I^2 0\%, 95\% CI: 0\%–51\%). The PI ranged from -0.16 to 0.44. Sensitivity analysis resulted in a similar non-significant effect (\( g = 0.13, P = 0.12 \)). Influence analysis in which the highest effect size was removed, resulted in a non-significant effect (\( g = 0.10, P = 0.09 \)) and removal of lowest effect size resulted in a significant effect size (\( g = 0.20, P = 0.03 \)). No outliers were detected.

In the main analysis, the pooled effect size for alcohol use at 6-month follow-up was small and significant with \( g = 0.14 \) (\( P = 0.005, 95\% \text{ CI: } 0.07 \text{ to } 0.20, NNT = 13.05, k = 5 \)). Heterogeneity was low (I^2 0\%, 95\% CI: 0\%–0\%), and the PI ranged from 0.05 to 0.22. The sensitivity analysis resulted in \( g = 0.14 \) (\( P = 0.27 \)); consequently, the confidence interval but not the effect size estimate is sensitive to statistical estimator choice. The influence analyses yielded effect sizes ranging from \( g = 0.11 \) to 0.15 (\( P = 0.03 \) and \( P = 0.0007 \), respectively), and no outliers were detected.

**DISCUSSION**

This study aimed to evaluate the effectiveness of digital interventions compared to any control group on depressive symptoms and alcohol use at different follow-up periods among people with co-occurring depression and problematic alcohol use. We found a small but significant effect in favour of digital interventions on depressive symptoms at 3-month follow-up and a non-significant effect for depressive symptoms at 6-month follow-up (\( g = 0.34 \) and 0.29, respectively). In addition, a non-significant effect (\( g = 0.14 \)) was found on alcohol use.
Table 2. Pooled effect sizes of digital interventions on alcohol use and depressive symptoms at 3- and 6-month follow-up

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Nc</th>
<th>Effect size</th>
<th>Heterogeneity estimators</th>
<th>Quality assessment</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>g</td>
<td>95% CI</td>
<td>P</td>
</tr>
<tr>
<td>Depressive symptoms at 3-month follow-up</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main analysis†</td>
<td>6</td>
<td>0.34</td>
<td>0.06 to 0.62</td>
<td>0.02</td>
</tr>
<tr>
<td>Additional analyses</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest ES removed‡</td>
<td>5</td>
<td>0.25</td>
<td>0.06 to 0.45</td>
<td>0.02</td>
</tr>
<tr>
<td>Lowest ES removed‡</td>
<td>5</td>
<td>0.41</td>
<td>0.10 to 0.73</td>
<td>0.02</td>
</tr>
<tr>
<td>Sensitivity analysis†</td>
<td>6</td>
<td>0.32</td>
<td>0.12 to 0.52</td>
<td>0.0014</td>
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<tr>
<td>Depressive symptoms at 6-month follow-up</td>
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<tr>
<td>Main analysis†</td>
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<tr>
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<td>6</td>
<td>0.14</td>
<td>−0.02 to 0.30</td>
<td>0.07</td>
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95% PI, prediction interval; additional analyses, influence analyses (leave-one-out analysis); ES, effect size; g, Hedges’ g; GRADE = very low, +; low, ++; moderate, +++; high, ++++; x, limitations in domain; ✓, not limitations in domain; Long-term, 6-month follow-up; N.a., not applicable, we were not able to assess publication bias; Nc, number of comparisons; Short-term, 1- to 3-month follow-up; T², Tau²; Q, Q-statistic.

†HKSJ estimator.
‡Omitting Agyapong et al. (2012).
§Omitting Geisner et al. (2015).
‖DL estimator.
¶Omitting Kay-Lambkin et al. (2009).
Fig. 3. Main meta-analyses on depressive symptoms and alcohol use at 3- and 6-month follow-up. Note: Wide 95% CI calculated on exact data as published in Deady et al. (2016).
at 3-month follow-up and a small but significant effect (g = 0.14) on alcohol use at 6-month follow-up. Sensitivity analysis indicated the confidence interval of the latter finding to be sensitive to statistical estimator choice. Statistical heterogeneity was low to moderate for both depression outcomes and low for alcohol use outcomes. The quality of evidence was moderate, except for depressive symptoms at 6-month follow-up for which evidence was low. Both GRADE ratings indicate that future research is likely to have an important impact on the confidence in the current findings and possibly change the estimates of the effects (Atkins et al., 2004). This uncertainty is also reflected in the PIs, which indicate that similar future studies could as well find positive or negative effects of digital interventions.

The current meta-analysis shows the preliminary beneficial effects of digital interventions in reducing depressive symptoms at 3-month follow-up and possibly alcohol use after 6-month follow-up. This observed effect on depressive symptoms (g = 0.34) is above the threshold for a clinically relevant effect for depression treatment (i.e. g = 0.24) (Cuijpers et al., 2014). Our findings seem partly in line with an older subgroup meta-analysis in which digital interventions were compared with face-to-face interventions, including 2 and 13 comparisons, respectively (Riper et al., 2014a). The authors found digital, exclusively CBT/MI-based interventions, for co-occurring depression and problematic drinking to outperform face-to-face CBT/MI in reducing depressive symptoms (g = 0.73 and g = 0.23, P = 0.030) but not for alcohol use (g = 0.39 and g = 0.16, P = 0.346) (Riper et al., 2014a). Effect size differences might be caused by differences in follow-up, comparators and included studies, as our review was not restricted to only CBT/MI-based interventions. Furthermore, we included mostly trials that compared self-guided digital interventions with active control groups. This often leads to small differential effect sizes. However, in our analyses, we found that studies with passive comparators did not have the largest effect sizes compared to active comparators. We hypothesise that this might have been caused by other factors such as intervention characteristics (e.g. mode of delivery, intensity, adherence) or participant characteristics.

Despite the fact that positive effects of digital interventions were not consistently found for both comorbid conditions, combined digital interventions might still have potential. First, for people who otherwise not seek professional care, digital treatment might be a suitable alternative (Schmidt, 2016; Kaner et al., 2017; Riper et al., 2018). Second, depression treatment alone is not always effective in reducing problematic alcohol use. A recent study showed that despite clinically relevant effects of both digital and regular depression treatment, alcohol use among depressed hazardous drinkers remained unchanged (Strid et al., 2019). Additionally, digital interventions for comorbid depression and problematic alcohol use are well-received by both professionals and patients (Deady et al., 2014). The majority of patients believed digital interventions (i.e. either supportive text messages or online CBT/MI modules) to be supportive and applicable in improving their mental well-being and controlling their alcohol use (Agyapong et al., 2013b; Deady et al., 2014). All in all, this shows that combined digital interventions have potential to be of value.

The fact that we only identified six RCTs and four protocol papers of ongoing trials on digital interventions for comorbid depression and problematic alcohol use shows that this is an emerging field. These ongoing trials can provide an important contribution to the field and possibly reduce inconsistencies regarding the current meta-analyses findings (Kay-Lambkin et al., 2015; Schaub et al., 2016; Cunningham et al., 2018; Frohlich et al., 2018). However, participant recruitment in previous studies has proven difficult and this may hinder fast progression in the field (Deady et al., 2016; Krause et al., 2019; O’Reilly et al., 2019). Clinical heterogeneity among included interventions was present due to differences in settings, duration, guidance and delivery-mode, but statistical heterogeneity was low to moderate. This might indicate that despite variations in interventions and populations, effects of the individual studies, although not all statistically significant, are quite homogeneous and often favour digital interventions over control conditions.

Limitations
Our findings should be interpreted in context of some limitations, such as the small number of included studies with sometimes small samples, which limits the power of the current study, and the inconsistencies in findings of the sensitivity analysis on alcohol use at 6-month follow-up. Furthermore, all studies had a high risk of bias and publication bias could not be assessed. Studies needed to have an abstract written in English in order to be identified in our search, which might have introduced language bias. Clinical heterogeneity was present among the included studies in terms of differences in intervention and population characteristics. Two studies were conducted on a mixed sample of depressed patients using cannabis and/or alcohol use in hazardous levels, for which we calculated the sample sizes for our comparison.

Future research
Future research is needed to replicate the current findings and to make the findings more robust. We did not observe consistent significant effects of digital interventions on both comorbid conditions at 6-month follow-up; more research is warranted that addresses this issue further and the possibility of lagged effects after this 6-month time point. To increase the quality of RCTs, researchers could consider including larger sample sizes, blinded clinician-rated outcomes in addition to self-report measures, pre-register trial protocols, adequate handling of missing data (e.g. multiple imputation) and uniform measurement and operationalization of alcohol use outcomes, for example by using outcomes included in the brief alcohol intervention core outcome set (Shorter et al., 2019). It would be of interest to report intervention adherence rates and include 12-month follow-up measurements and evaluate cost-effectiveness. Researchers could consider developing interventions that are accessible on smartphones or smartphone app-based and evaluate in what type of setting and for what type of clients digital interventions are especially beneficial. In this way, more efficient use of digital interventions might be accomplished, which could benefit implementation in practice. Lastly, an individual patient data meta-analysis could possibly resolve some of the current shortcomings (e.g. increase in power, reliability and standardisation in analysis) of this traditional meta-analysis (Riley et al., 2010).

CONCLUSION
Despite its limitations, this meta-analysis provides evidence of the effectiveness of digital interventions for people with co-occurring depression and problematic alcohol use. Our findings indicate that digital interventions can have a positive effect on depressive symptoms at 3-month follow-up and alcohol use at 6-month follow-up. More research is needed to corroborate the current findings and enhance evidence-based treatment options for people with comorbid depression and problematic alcohol use.

SUPPLEMENTARY MATERIAL
Supplementary material is available at Alcohol and Alcoholism online.
ACKNOWLEDGEMENTS

We would like to thank Caroline Planting for her help with the development of the search strategies.

DATA AVAILABILITY

The data underlying this article are available in DANS EASY, at https://doi.org/10.17026/dans-xfm-g98b.

CONFLICT OF INTEREST STATEMENT

None declared.

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